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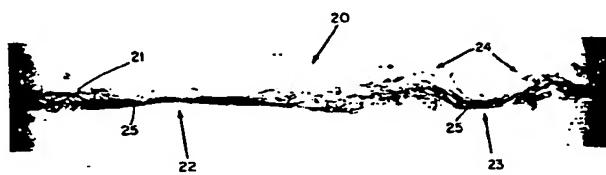
⑯ Pattern densified fibrous web having spaced, binder impregnated high density zones, and method of making such a web.

⑯ The invention provides a soft, pattern densified fibrous web such as a paper sheet which web generally comprises a relatively low bond, high bulk, vaulted field and a patterned array of spaced zones of relatively high fibre density, at least a substantial proportion of which dense zones are at least partially impregnated with binder material. The degree of impregnating and bonding in the dense zones may be increased by applying mechanical compression to the impregnated zones subsequent to applying the binder material.

A method of making such a web is also disclosed. The method generally entails forming a low bond, pattern densified fibrous web; supporting dense zones of the web on a patterned array of spaced supports; displacing the unsupported portions of the web into the spaces intermediate the spaced supports; and applying a binder material to dense supported zones of the web.

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PATTERN DENSIFIED FIBROUS WEB  
HAVING SPACED, BINDER IMPREGNATED HIGH  
DENSITY ZONES, AND METHOD OF MAKING SUCH A WEB

Technical Field

This invention relates to soft fibrous webs such as paper for paper towels and tissue paper, and a method of making such a web which is reinforced at 5 least in part by binder material.

Background Art

In general, the exemplary patents described below disclose soft, relatively high bulk webs such as paper, and concomitant processes, some of which include pattern 10 applied binder materials such as elastomers for the purpose of strengthening the fibrous webs without making them inordinately inflexible or hard or harsh to feel.

US Patent No 2,039,312 which issued May 5, 1936 15 to J H Goldman discloses a Reinforced Carded Web which may be reinforced by a reticulated network of narrow lines of impregnation with a suitable binder which lines are preferably spaced slightly less than the average fibre length of the fibres constituting the 20 web.

US Patents No 2,880,111 and No 3,009,822 which issued to A H Drelich et al on March 31, 1959 and November 21, 1961, respectively, disclose fibrous Textile-Like Nonwoven Fabrics wherein the fibres are 25 held together by an adhesive or bonding material disbributed amongst them in predetermined patterns of closely spaced discrete areas. The latter patent

also discloses lined patterns of binder as well as a rotogravure method of making such fabrics which includes the step of wetting a fibrous web prior to rotogravure printing a predetermined pattern of spaced binder segments.

5 US Patent No 3,301,746 which issued January 31, 1967 to Lawrence H Sanford and James B Sisson covers a Process for Forming Absorbent Paper by Imprinting A Fabric Knuckle Pattern Thereon Prior To Drying And 10 Process Thereof. Briefly, a high bulk fibrous web is wet formed and predried to a fibre consistency of from about 30 to about 80 percent by avoiding substantial mechanical compression until the web is predried; then a knuckle pattern of an imprinting fabric is imprinted 15 in the predried web while the remainder remains substantially uncompacted. The web may also be somewhat molded to the surface of the imprinting fabric by differential fluid forces prior to the predrying. Upon being imprinted, the imprinted zones become compacted 20 and relatively highly hydrogen bonded due to the imprinting pressure and the water remaining in the predried web prior to final drying. Thus, upon final drying, the resulting paper is pattern compacted and bonded in the image of the knuckle pattern of the 25 imprinting fabric. It is believed that such a paper is soft and bulky because of not being compacted overall and because the fibres disposed in the uncompacted portions do not become highly hydrogen bonded as in theretofore conventional felt-pressing papermaking.

30 US Patent No 3,994,771 which issued November 30, 1976 to George Morgan Jr et al extended this technology to a Process for Forming A Layered Paper Web Having Improved Bulk, Tactile Impression And Absorbency And Paper Thereof.

35 US Patent No 4,158,594 which was filed June 24, 1971 and issued June 19, 1979 to Henry E Becker et al discloses Bonded, Differentially Creped, Fibrous Webs

And Method of Making Same wherein creping bonding material such as latex is pattern gravure printed onto a dried, self-supporting fibrous web having relatively low interfibre bonding strength. The web is preferably 5 creped prior to printing, and is printed while being forwarded onto a creping cylinder from which it is subsequently differentially creped. This patent recites that it is particularly desirable to apply the bonding material in a reticular pattern so that the 10 bonding material forms a net-like web of strength over the fibrous web. Indeed, all of the disclosed examples were printed with a reticular pattern although both discrete spot bonding and reticular pattern bonding are shown in the figures. This technology was apparently 15 broadened somewhat by the following commonly assigned patents although all commonly show gravure printing of bonding material onto dried, self-supporting fibrous webs: US Patents No 3,879,257 which issued April 22, 1975; No 3,903,342 which issued September 2, 1975; 20 and No 4,000,237 which issued December 28, 1976.

US Patent No 3,812,000 which issued May 21, 1974 to J L Salvucci et al discloses a Soft, Absorbent, Fibrous, Sheet Material Formed By Avoiding Mechanical Compression Of The Elastomer Containing Fiber Furnish 25 Until The Sheet Is At Least 80% Dry. As disclosed, an elastomeric bonding material is included in the fibre furnish so that it is distributed throughout the finished sheet. Additionally, more such bonding material may be applied to the sheet in a predetermined 30 pattern by a patterned gravure roll while the sheet is being forwarded through a papermachine on a foraminous drying fabric. The pattern is stated to preferably be a reticular hexagonal pattern. As compared to the Sanford-Sisson patent described above, Salvucci et al 35 include elastomeric material in a low-bond furnish; predry to a greater extent; and may gravure print a pattern of additional binder material on the web with

a patterned gravure roll. However, Salvucci et al expressly teach away from pattern knuckle compaction as taught by Sanford-Sisson because "the pressures generated by the knuckle pattern of the woven wire are so high as to create hard portions of the web which give a feeling of harshness to the resulting product".

5 US Patent No 3,898,123 which issued August 5, 1975 to Charles H. Phillips et al discloses a Method For Wet Print-Bonding Light-Weight Wet-Formed Fibrous Webs 10 wherein a self-supporting, wet-formed web has an aqueous resin binder applied by print-bonding rolls having etched or engraved printing surfaces, and which binder material is applied intermediate two open draw free spans of the web prior to drying the web.

15 US Patent No 4,127,637 which issued November 28, 1978 to Eugene J. Pietreniak et al discloses a Method Of Manufacturing A Dry-Formed, Embossed Adhesively Bonded, Nonwoven Fibrous Sheet having spaced uncompacted fibrous zones on a compacted reticulated fibrous 20 network wherein binder material is preferably disposed in the uncompacted zones and through the compacted network.

25 US Patent No 4,159,355 which issued June 26, 1979 to Kenneth Kaufman discloses Foam Bonding method and apparatus for applying a foamed binder in a uniform and controlled metered flow to a surface of a moving substrate such as a nonwoven web.

30 Additionally, a paper entitled Forming Of Low Density Nonwoven Fabrics: Technology And Direction was presented by G A M Butterworth on November 13, 1979 at the International Air Laid And Low Density Forming Seminar at the Hyatt Regency Hotel in Atlanta, Georgia. This paper provides a consolidated discussion of patents pertaining to low density webs 35 including webs which are at least partially impregnated with, for instance, binder material.

While not intending to limit the present invention to the following generalized distinctions, the present invention provides, as compared to the foregoing background art, a generally relatively low bond, high bulk, 5 highly flexible pattern densified web such as a paper sheet having spaced discrete zones of relatively high fibre density which zones are sufficiently impregnated with binder material to provide adequate sheet tensile strength without compacting or impregnating the surrounding 10 low density portions of the web; and the present invention provides a concomitant method of making such a web. That is, the background art does not disclose applying binder material to only relatively dense zones 15 of a fibrous web having a patterned array of spaced discrete high fibre density zones as provided by the present invention.

Disclosure of the Invention

In accordance with one broad aspect of the present invention there is provided a pattern densified 20 fibrous web and concomitant method of making such a web which web has a relatively high bulk field of relatively low fibre density, and a patterned array of spaced zones of relatively high fibre density at least a substantial proportion of which zones are at 25 least partially impregnated with binder material, and in which web the high bulk field is substantially uncompacted and devoid of such binder material. The concomitant method comprises the steps of forming a pattern densified embryonic web having an array of 30 discrete high density zones disposed in a predetermined pattern; supporting the embryonic web on a corresponding array of spaced supports so that at least each of a predetermined sub-array of the dense zones is juxtaposed one of a corresponding sub-array of the supports; 35 and biasing the sub-array of supports towards a contacting type impregnating means with the sub-array of dense zones disposed therebetween so that, through

coincidence of at least a substantial number of the supports of the sub-array and binder transfer portions of the impregnating means, at least a substantial proportion of the dense zones become at least partially impregnated. In the method, the array of spaced supports may be the knuckles of an endless imprinting carrier fabric and the sub-array of such supports may be only the top-surface-plane knuckles of the fabric in fabrics having both top-surface-plane knuckles and sub-top-surface knuckles. In fabrics having no sub-top-surface knuckles the sub-array of supports would in fact be the array of supports. For maximum strength, all of the high density zones are impregnated with binder material whereas only some may only be partially impregnated in sheets wherein partial impregnation provides sufficient sheet strength for the intended use of the sheets. Impregnating means such as a full field gravure applicator may be used to impregnate the dense zones of the web biased against it whereas less-than-full-field gravure applicators may be used to only partially impregnate all or some of the dense zones of the web, or wholly impregnate only some of the dense zones. Moreover, the method may further comprise the step of subjecting the impregnated zones to further mechanical pressure/compaction after they are impregnated to increase the binder penetration and interfibre bonding therein.

Brief Description of the Drawings

While the specification concludes with claims particularly pointing out and distinctly claiming the subject matter regarded as forming the present invention, it is believed the invention will be better understood from the following description taken in conjunction with the accompanying drawings in which corresponding features are identically designated, and in which:

Figure 1 is an enlarged photographic sectional view of a fragmentary sheet of paper embodying the present invention.

5 Figure 2 is a fragmentary plan view drawing of a sheet of paper embodying the present invention which sheet comprises a predetermined pattern of spaced high density zones disposed on a relatively high bulk field.

10 Figure 3 is a fragmentary sectional view drawing of a sheet of paper embodying the present invention which sectional view is taken along line 3-3 of Figure 2, and which sectional view generally corresponds to the photographic sectional view of Figure 1.

15 Figure 4 is a fragmentary sectional view drawing of a sheet of paper which is substantially identical to that shown in Figure 3 except the flat, high density zones of the Figure 4 sheet are not impregnated with binder material.

20 Figure 5 is a side elevational, somewhat schematic view of a papermaking machine for manufacturing a wet laid fibrous web such as paper in accordance with the present invention.

25 Figure 6 is a fragmentary plan view of an exemplary imprinting carrier fabric such as may be used on the papermaking machine shown in Figure 5 and which imprints its top-surface-plane knuckle pattern into a web such as a sheet of paper to precipitate a pattern of compacted zones.

30 Figure 7 is a radially inwardly looking fragmentary view of the surface of a rotogravure cylinder having a full field of truncated pyramidal reservoirs formed therein, and having a partially peeled back opaque overlay disposed thereon which overlay is apertured 35 in the knuckle pattern of the imprinting carrier fabric shown in Figure 6.

Figures 8 through 12 are partially masked fragmentary rotogravure cylinders which are substantially identical to that shown in Figure 7 except the cylinders of Figures 8 through 12 are less-than-full-field micro-patterned to provide reservoirs over only about 75, 50, 50, 50 and 25 percent, respectively, of their cylindrical surface areas.

Figure 13 is a somewhat schematic side elevational view of a handsheet impregnating apparatus.

Figure 14 is an enlarged scale, fragmentary view of the roller-nip portion of the apparatus shown in Figure 13 and through which nip portion a handsheet disposed on an imprinting carrier fabric, and a flat gravure plate are being forwarded in juxtaposed relation.

Figure 15 is an enlarged scale, fragmentary view similar to Figure 14 except the handsheet of Figure 15 is not disposed on an imprinting carrier fabric as shown in Figure 14.

#### 20 Detailed Description of the Invention

A fragmentary portion of a microtomed section of a paper sheet embodying the present invention is shown in the photographic Figure 1 to comprise a fibrous web 20 comprising a multiplicity of fibres 21 which are disposed in relatively high density zones 22 and 23, and arcuate-shape relatively low density span portions 24, and in which web the high density zones 22 and 23 are impregnated with a latex fibre binder material 25.

Briefly, as described more fully hereinafter in conjunction with discussing web 20, Figures 2, 3 and 4, the present invention provides a soft, pattern densified fibrous web such as a paper sheet which comprises a relatively low density fibrous field and a multiplicity of relatively high density fibrous zones disposed in a predetermined array, and in which web each of at least a substantial proportion of such dense zones are at

least partially impregnated with a binder material of a type which provides interfibre bonds which are preferably substantially more flexible than ordinary interfibre hydrogen bonds which occur between cellul-  
5 osic fibres in ordinary papermaking. The web comprises a principal web-strength fibre constituent comprising fibres of sufficient average length with respect to the spacing of the impregnated high density zones that a substantial fraction of the fibres will have spaced  
10 portions thereof disposed in adjacent impregnated dense zones and in overlapping bonded relation with portions of other fibres so that the bonded principal web-strength fibres constitute a strength-skeletal-network of the web. Preferably, the low density field  
15 comprises arcuate-shape spans which are so disposed with respect to the dense zones that the web has a vaulted character. Also, preferably: the principal web-strength fibres have average lengths of about 2.0 mm or greater (e.g. softwood fibres); but for the  
20 impregnated dense zones, the web is characterised by a relatively low degree of interfibre bonding which may be achieved by including debonders in the furnish, or through the use of low bond fibres; and the dense zones preferably are equal in number to the number of  
25 imprinting knuckles of an imprinting fabric having a mesh count of from 10-MD/10-CD to 60-MD/60-CD filaments per inch (from 4 by 4 to 24 by 24 machine direction filaments and cross machine direction filaments per centimetre, respectively) and more preferably from  
30 20-MD/20-CD to 50-MD/50-CD filaments per inch (from 8 by 8 to 30 by 20 machine direction filaments and cross machine direction filaments per centimetre, respectively).  
Briefly, a web embodiment of the present invention as described above is preferably made by forming a  
35 pattern densified web of fibres of appropriate lengths, flexibility, and bonding propensity; supporting high density zones of the web on an array of spaced supports

which are preferably generally coplanar; deflecting the webs low density span portions out of the plane of the supports; and impregnating at least a substantial proportion of the dense zones. The degree of impregnation and/or bonding may be increased by subjecting the high density zones to mechanical compression after the basic impregnation has been effected. For instance, a wet formed embryonic web may be so pattern densified and deflected by a differential fluid pressure while the embryonic web is disposed on an appropriate imprinting carrier fabric as described hereinafter in conjunction with discussing Figure 6; and the impregnating may be effected, for instance, by a pressure biased gravure apparatus as also described hereinafter. Preferably, the web is also creped, calendered and reeled after being impregnated and dried to further increase its stretch, bulk and softness, and to control its caliper.

Referring again to Figure 1, web 20 and the preferred process for making it in accordance with the present invention are described hereinafter as paper sheet 20 and papermaking processes, respectively, although it is not intended to thereby limit the present invention.

Figure 3 is a fragmentary sectional view drawing of a paper sheet 20 embodying the present invention which view is taken along line 3-3 of Figure 2, and which sectional view drawing generally corresponds to the photographic sectional view of Figure 1. That is, paper sheet 20 is shown in Figure 3 to comprise arcuate-shape low density span portions 24 which are alternately spaced by relatively long and short high density zones 22 and 23 respectively, which dense zones are generally planar and are impregnated with binder material 25. As may be seen in Figure 2, a multiplicity of dense zones 22 and 23 are disposed in a predetermined pattern or array on a generally low density field of which

portions 24, Figure 3, are representative.

Figure 4 is a fragmentary sectional view drawing of a pattern densified paper sheet 20a which generally corresponds with paper sheet 20, Figure 3, except paper sheet 20a is not impregnated with binder material. That is, paper sheet 20a is a pattern densified web which has not had its high density zones impregnated with binder material in accordance with the present invention. Also, the relative fibre density of zones 22a and 23a of unimpregnated sheet 20a is shown to be somewhat less than the fibre density of zones 22 and 23 of sheet 20 because zones 22a and 23a have not been subjected to the mechanical compaction experienced by zones 22 and 23 through the practice of the present invention as hereinbefore described.

Figure 5 is a fragmentary, somewhat schematic side elevational view of an exemplary papermaking machine 30 through the use of which paper sheet embodiments of the present invention can be made and the process of the present invention can be practised. Papermaking machine 30 is a fixed roof former type papermaking machine wherein a fibrous slurry is delivered from a headbox 32 onto a Fourdrinier wire 33 passing over a vacuum type breast roll 34. The Fourdrinier wire then passes over a forming board 35 and suction box 36 and is further looped about turning rolls 41 through 46. The slurry is partially dewatered by the vacuum and table roll action of the breast roll. Further dewatering is precipitated by forming board 35 and suction box 36 so that an embryonic fibrous web 20e is formed and forwarded on the Fourdrinier wire to a first transfer station generally designated 50 where it is transferred from Fourdrinier wire 33 to an endless intermediate carrier fabric 51 which partially wraps roll 42, passes over suction boxes 52 and 53, then over vacuum transfer box 54, and then is looped about rolls 55, 56, 57 and

58. Dewatering is furthered as the embryonic web 20e is forwarded in sandwiched relation between Four-drinier wire 33 and fabric 51 past suction boxes 52 and 53, and then over a portion of vacuum transfer  
5 box 54 after which the embryonic web 20e is disposed and forwarded on fabric 51 to an endless imprinting carrier fabric 59 at a second transfer station designated 60. At the second transfer station 60, embryonic web 20e is transferred by the action of vacuum transfer  
10 box 61 from the intermediate carrier fabric 51 to the imprinting carrier fabric 59 which is looped past/about suction box 62, turning roll 63, blow through predryer 64, impregnating means 65, turning roll 66, pressure roll 67, turning roll 68, showers 69, suction  
15 box 70, and turning rolls 71 and 72. At this time, formation of the web continues due to the differential fluid pressure applied to the web to effect the second transfer and fibre mobility enabled by a sufficiently high water content (preferably a fibre consistency of  
20 30 percent or less), the embryonic web becomes pattern densified with dense zones of fibres juxtaposed the knuckles of the imprinting carrier fabric 59. After being transferred to the imprinting carrier fabric 59, the embryonic web is further dewatered by suction box  
25 62 and blow through predryer 64; then partially impregnated with binder material 25 by pressure biased impregnating means 65; and then transferred to Yankee dryer 75 by the action of pressure roll 67 which is biased towards the Yankee dryer by biasing means 76.  
30 Transfer of the web to the Yankee dryer and adherence thereto is enabled by creping adhesive applied through applicator 77. Finally, upon being fully dried on the Yankee dryer, the transformation of embryonic web 20e to paper sheet 20 is completed as the final drying  
35 thereof is effected and, preferably, it is creped from the Yankee dryer by the action of doctor blade 78.

Preferably, the paper sheet 20 is then calendered and reeled to control its caliper and enable its subsequent conversion from reels into paper products such as paper towels, toilet and facial tissue paper. Also, 5 in the event the binder material requires curing, such curing may be effected at least in part after the paper sheet has been removed from the papermaking machine.

Figure 6 is a plan view of the top, outwardly facing surface of an exemplary imprinting carrier fabric 59 which may be used on a papermaking machine such as papermaking machine 30, Figure 5, to practise the present invention. Fabric 59 is a five-shed satin weave of polyester monofilaments which were woven using a 1, 4, 2, 5, 3 warp pick sequence and wherein the 10 filaments 90-1 through 90-5 which extend in the machine direction, MD, alternatively pass over four and under one of the filaments 91-1 through 91-5 which extend in the cross machine direction, CD; and wherein the CD filaments alternately pass over one and under 15 the filaments 90-1 through 90-5 which extend in the machine direction, MD, alternatively pass over four and under one of the filaments 91-1 through 91-5 which extend in the cross machine direction, CD; and wherein the CD filaments alternately pass over one and under 20 four MD filaments. Fabric 59 has been stressed, heat set, and sanded to provide coplanar sets of long MD imprinting knuckles 92, and relatively short 1-over CD imprinting knuckles 93. The outwardly facing surfaces of coplanar sets of knuckles 92 and 93 corporately 25 define a top-surface-plane of fabric 59. Fabric 59 also has adjacent pairs of sub-top-surface filament crossovers designated 94 which, by virtue of the weave, stressing, and heat setting are recessed below the top-surface-plane of the fabric. Such a fabric is described 30 more fully in Trokhan US Patent No 4,329,065 issued December 16, 1980. Also, such a fabric is particularly useful for making soft and absorbent imprinted paper having uncompressed portions circumscribed by picket-like lineaments of alternately spaced areas of compacted 35 fibres and non-compacted fibres which compacted fibre areas or zones are precipitated by imprinting the top-

surface-plane knuckles of the fabric into a relatively uncompacted, low density, high bulk paper sheet.

This is more fully described in the commonly assigned Trokhan US Patent 4,191,609 issued March 4, 1980.

5 While the 5-shed fabric 59, Figure 5, has been described above as exemplary with respect to the present invention it is not intended to thereby limit the present invention to any particular fabric weave, or knuckle geometry or disposition.

10 Impregnating means 65, Figure 5, comprises rotogravure cylinder 81, backing roll 82, biasing means 83, and reservoir 85 which is adapted by means not shown to maintain a relatively constant predetermined level of liquid impregnating material 25 therein. This 15 level insures that a downwardly facing arcuate portion of rotogravure cylinder 81 is immersed in the impregnating material. Doctor means, not shown, are provided for removing the excess impregnating material from the rotogravure cylinder as it rotates upwardly towards 20 the travelling embryonic web. Synchronous drive means, not shown, may also be provided as needed to obviate deleterious drag on the embryonic web as it passes through the nip between rotogravure cylinder 81 and backing roll 82. While as described, impregnating 25 means 65 of papermaking machine 30 is a gravure type applicator, it is not intended to thereby limit the present invention to gravure applicators or impregnators. Rather, it is believed that other contacting type applicators such as, for instance, foam 30 applicators may be used to practise the present invention.

Figure 7 is an enlarged scale, radially inwardly looking view of a fragmentary portion of an exemplary rotogravure cylinder 81 which has its cylindrical surface covered by a partially peeled back, opaque mask 96 which is apertured in the top-surface-plane

knuckle pattern of imprinting carrier fabric 59, Figure 6. That is, apertures 92a and 93a in mask 96 are sized and disposed in the image of the top-surface-plane knuckle pattern of fabric 59, Figure 6.

5 The entire gravure surface of rotogravure cylinder 81 is defined by a full field pattern of truncated pyramidal cavities or reservoirs 100. In use, as an embryonic web 20e is carried through the nip of impregnating means 65 of papermaking machine 30, Figure 4, only

10 the dense zones of the web which are juxtaposed top-surface-plane knuckles 92 and 93 of fabric 59 are biased against the rotogravure cylinder 81. This substantially limits the pattern of impregnation to the pattern of the high density zones juxtaposed the

15 top-surface-plane knuckles 92 and 93 of fabric 59. Thus, the pattern of impregnation is determined by the imprinting carrier fabric rather than a pattern on the rotogravure cylinder. Also, the pattern of impregnation of the web is in registration with the

20 pattern of dense zones of the web as illustrated in web 20, Figures 1 and 3. However, the area of the web which becomes impregnated may in fact be substantially larger than the sanded areas of knuckles 92 and 93 because the filaments of the woven fabric 59

25 gradually slope away from the sanded areas of the knuckles and thus cause web portions contiguous thereto to be impregnated along with the web portions immediately juxtaposed the sanded areas of the knuckles. Furthermore, it is believed that the absence of bias-

30 ing of the unsupported span portions of the embryonic web substantially obviates transfer of binding material thereto from rotogravure cylinder 81. Moreover, displacement of the unsupported span portions into the interfilamentary spaces of the imprinting fabric may

35 be effected to virtually totally obviate their being impregnated by rotogravure cylinder 81.

Figures 8 through 12 are similar to Figure 7 except the alternate embodiment rotogravure cylinders 81a through 81e of Figures 8 through 12, respectively, are provided with less-than-full-field checkerboard type patterns of reservoirs 100 which reservoirs cover 75, 50, 50, 50 and 25 percent, respectively, of the working surfaces of cylinders 81a, 81b, 81c, 81d and 81e. Thus, such less-than-full-field patterned rotogravure cylinders will coact with a patterned imprinting fabric to apply impregnating material to only the surface portions of an embryonic web which are in registered relation with top-surface-plane knuckles and adjacent reservoir portions of the rotogravure cylinder pattern. Such patterned cylinders are useful with respect to providing various degrees of web strength through binder impregnation while preserving various complementary degrees of binder-free surface areas. Thus, strength may be increased by impregnating larger percentages of web surface area. Furthermore, whereas the alternate embodiment, less-than-full-field, rotogravure cylinders 81a through 81e have relatively small checkerboard-type patterns with respect to the knuckle pattern of fabric 59, Figure 6, less-than-full-field patterns (not shown) having larger open (non-printing/non-impregnating) areas may be used to assure not impregnating a substantial proportion of the dense zones as well as concurrently assuring that a substantial proportion of the dense zones will be impregnated. This is useful when, for instance, creping of the finished web is desired and the binder substantially vitiates the intended function of a creping adhesive (e.g. polyvinyl alcohol applied by spray applicators 77, Figure 5). The proportion of binder impregnated zones is maintained great enough to provide adequate web strength while the proportion of non-binder-impregnated zones is made great enough to enable the creping adhesive to securely affix those zones to the Yankee dryer (creping cylinder)

to control the web and the creping thereof in substantially the manner disclosed in the hereinbefore referenced Sanford-Sisson patent.

Figure 13 is a somewhat schematic side elevational view of a handsheet impregnating apparatus 106 which comprises rotatably mounted, rubber covered rolls 107 and 108, a slanted feed plate 109, a horizontal feed plate 110, and a receiving plate 111. Means not shown are provided to pressure bias rolls 107 and 108 together, and to synchronously rotate rolls 107 and 108 in the directions indicated by the arrows drawn thereon.

Figure 14 is a fragmentary enlarged scale view of the nip portion of apparatus 106, Figure 13, which view shows fragmentary sections of rolls 107 and 108, a gravure plate 115, and a paper handsheet 116 disposed on the under side of an imprinting carrier fabric 117. Figure 15 is substantially identical to Figure 14 except the handsheet 116 in Figure 15 is self-supported, i.e. not disposed on an imprinting carrier fabric.

In use, referring to handsheet impregnating apparatus 106, Figures 13 through 15, a gravure plate 115 is placed on plate 110 with its pattern side up and with its cells filled with binder material. Then, a handsheet 116 is placed on plate 109. Handsheet 116 may be associated with an imprinting carrier fabric 117 as indicated in Figure 14, or not so associated as indicated by the absence of such a fabric 117 from Figure 15. Then, rolls 107 and 108 are biased together with a predetermined force and rotated synchronously while the handsheet 116 and the gravure plate 115 are simultaneously moved so that their leading edges enter the nip between the rolls. Thus, as the handsheet and gravure plate pass through the nip, the handsheet becomes impregnated. When the web is associated with a fabric during impregnation as shown in Figure 14, the pattern of web impregnation is the knuckle pattern

of the fabric when a full field gravure plate is used. Therefore, when the handsheet has been pattern densified by formation on an imprinting carrier fabric so that the dense zones of the handsheet are juxtaposed 5 the knuckles of the imprinting carrier fabric, only the dense zones of the handsheet become impregnated by a full field gravure plate through the use of handsheet impregnating apparatus 106.

Briefly, referring back to Figure 5, an embryonic 10 web 20e is preferably formed and forwarded without subjecting it to substantial mechanical compaction until it reaches the impregnating means 65. By including a principal web-strength fibre constituent 15 in the furnish which constituent consists of fibres having a predetermined average length relation with respect to the knuckle pattern of the imprinting carrier fabric 59, and by controlling dewatering a pattern densified embryonic web may be formed in which web relatively high fibre density zones are juxtaposed 20 the outwardly facing knuckles of imprinting carrier fabric 59, and in which web the remaining portions which are unsupported and span the spaces between the knuckles have relatively low fibre density. Preferably, the unsupported spans are also acted on 25 by sufficient differential fluid pressure while the web is at a sufficiently low fibre consistency to sufficiently displace the unsupported spans into the interfilamentary spaces between the knuckles of the imprinting carrier fabric to obviate their being 30 impregnated by impregnating means 65 although it is not intended to thereby limit the present invention. The embryonic web is preferably predried to from about 30 to about 95 percent fibre consistency and more preferably to from about 60 to about 90 percent 35 fibre consistency prior to being impregnated. Also, preferably the drying is sufficiently asymmetrical to

dry the unsupported portions of the web substantially more than the dense portions. This may be effected, for instance, by blow through predrying of the web while it is disposed on the imprinting carrier fabric of papermaking machine 30. This enhances the Z-direction penetration of the binder material through the thickness of the web and lessens the propensity of the binder material to migrate laterally in the X-Y directions into the low density portions of the web.

10 Such X-Y migration into the low density portions of the web from the high density zones is further inhibited due to their relative capillary structures: i.e. normally capillary flow is greater from low density to high density zones than from high density to

15 low density zones. Moreover, with respect to latex type binder emulsions in particular, it is believed that the commencement of X-Y migration from relatively wet zones into dry areas acts to dewater such emulsions and cause them to coagulate rather than

20 migrate very far into the dry areas.

In addition to the impregnation of the high density zones which is effected as the web is carried on the imprinting carrier fabric 59 through the pressure biased impregnating means 65, Figure 5, the biasing

25 also precipitates some compaction of and bonding within the high density zones of the web. Subsequently, as the high density zones of the web are again subjected to knuckle pressure between pressure roll 67 and Yankee dryer 75, the penetration of the binder is

30 enhanced, and the degree of compaction and bonding within the high density zones is increased.

A number of handsheet examples as well as papermaking machine examples are described below. Briefly, the handsheet examples evidence the benefits of impregnating only dense zones of a pattern densified paper sheet in accordance with the present invention; and the papermaking machine examples evidence the benefit

of subjecting impregnated, high density zones to further mechanical pressure after the impregnating, and the benefits which may be derived from the present invention through the use of different impregnating 5 materials.

HANDSHEET EXAMPLE I

A pattern densified, one foot square (30 cm square) handsheet having a basis weight of 16.5 pounds per 3000 square feet (27 grams per square metre) was 10 formed from a fibrous furnish on a foraminous poly-ester fabric of the 5-shed satin weave shown in Figure 6 and having a 36-MD/32-CD filaments per inch (14-MD by 12.6-CD filaments per centimetre) mesh count. The furnish comprised 60 percent by fibre weight of 15 Tongacel (registered trademark of Louisiana Pacific Corporation) K 324N, a relatively low bond, long fibre, post bleach cold caustic extracted dissolving grade Northern Softwood Sulfite which is available from Louisiana Pacific Corporation, and 40 percent by fibre 20 weight of relatively long softwood fibres which were obtained from the Buckeye Cellulose Corporation under the designation Grand Prairie Prime, a Northern Softwood Kraft. After formation and draining, the handsheet was further dewatered by pulling the fabric with 25 the handsheet disposed thereon over a vacuum slot having 10 inches (25.4 centimetres) of mercury vacuum applied thereto. The handsheet was then dried on a can type dryer while still disposed on the fabric and in its original relation thereto. The dried handsheet was 30 then impregnated in its zones juxtaposed the top-surface-plane knuckles of the fabric by passing the fabric/sheet combination and a full-field gravure plate through the handsheet impregnating apparatus 106 as indicated in the enlarged scale Figure 14 and as 35 hereinbefore described. The latex binder comprised a 25 percent solids, self-crosslinking acrylic latex

emulsion which was obtained from Rohm and Haas Company, Philadelphia, Pennsylvania, and which was designated TR-520. The latex binder further comprised ammonium nitrate ( $\text{NH}_4\text{NO}_3$ ), a latent acid catalyst, 5 in the amount of 0.5 percent by weight of latex solids; Pluronic L-92 of 1.0 percent by weight of latex solids, which is a nonionic surfactant sold by BASF Wyandotte Corporation, Parsippany, New Jersey, and which was added to serve as a finished product 10 wetting agent; ammonium hydroxide ( $\text{NH}_4\text{OH}$ ) in sufficient amount to raise the pH of the binder solution to 5.0; Lithium Acetate ( $\text{CH}_3\text{CO}_2\text{Li}$ ) in the amount of 200 ppm Lithium based on the weight of latex solids to serve as a tracer to facilitate analysis of samples 15 to ascertain their latex content; and an anionic water soluble dye was added to allow visual inspection of the impregnation pattern. The gravure plate was etched to provide a full field of reservoirs which numbered 22,500 reservoirs per square inch (3500 reservoirs per square centimetre) and the corporate 20 volume of the reservoirs was 1.2 microlitres per square centimetre of etched area.

HANDSHEET EXAMPLE 2

Handsheat Example 2 was a replicate of Handsheet 25 Example 1 insofar as variables in the making thereof permitted.

HANDSHEET EXAMPLE 3

Handsheat Example 3 was prepared like Handsheet Examples 1 and 2 except for Number 3 the etched, full 30 field gravure pattern comprised 40,000 reservoirs per square inch (6200 reservoirs per square centimetre), and the corporate volume of the reservoirs was 2.2 microlitres per square centimetre.

HANDSHEET EXAMPLE 4

Handsheet Example 4 was prepared like Handsheet Example 1 except that after it was dried on its forming fabric it was removed therefrom, rotated 90 degrees with respect thereto, and reassociated therewith with adhesive tape. Thus, the pattern of the zone densified handsheet was placed out of registration with the knuckle pattern of the fabric prior to impregnation so that comparative data could be obtained with respect to out-of-registration impregnation (Handsheet Example 4) versus in-registration impregnation (Handsheet Examples 1, 2 and 3) of pattern densified fibrous webs.

HANDSHEET EXAMPLE 5

Handsheet Example 5 was prepared like Handsheet Example 4 except, prior to impregnation, the densified structure of the handsheet was placed out of registration with the knuckle pattern of the fabric by removing the handsheet from the fabric and turning the handsheet over prior to reassociating it with the fabric with adhesive tape. This handsheet provided further out-of-registration-impregnation data which is tabulated along with the corresponding data from Handsheet Examples 1 through 4 in Table I.

HANDSHEET EXAMPLE 6

Whereas Handsheet Examples 1 through 5 were pattern densified during their formation on relatively coarse 36 x 32 mesh fabrics of the 5-shed satin weave shown in Figure 6, Handsheet Example 6 was formed with relatively uniform density on a relatively fine mesh fabric having 110 x 95, MD x CD filaments per inch (43 x 37, MD x CD filaments per centimetre), and woven with a 4-shed satin weave using a 1, 2, 3, 4 warp pick sequence. But for the different forming fabrics, Handsheet Example 6 was made and dried in the same

manner and of the same furnish as Handsheet Example 1. However, because the relatively fine mesh 4-shed satin weave fabric described above is much smoother than the relatively coarse 5-shed fabric shown in

5 Figure 6, and because the fibres of the furnish were very long with respect to the knuckle-to-knuckle span of the 110 x 95, 4-shed as compared to the coarser 36 x 32, 5-shed fabric, the handsheet formed on the 4-shed was relatively uniformly dense as compared

10 to the pattern densified Handsheet Examples 1 through 5, inclusive. But, it is not intended to thereby imply that pattern densified sheets cannot be formed on fine mesh fabrics such as the 4-shed satin weave described above. After being dried, Handsheet

15 Example 6 was removed from the 110 x 95 forming fabric and taped onto a 36 x 32 mesh, 5-shed fabric identical to those used for Handsheet Examples 1 through 5 prior to being impregnated by passing it through handsheet impregnating apparatus 106 in the

20 manner indicated in Figure 14. The gravure plate and the latex binder composition were also the same for Handsheet Example 6 as for Handsheet Examples 1, 2, 4 and 5. Thus, Handsheet Example 6 was a pattern impregnated sheet of relatively uniform

25 density which yielded data which is also tabulated in Table I for conveniently comparing the pattern densified/pattern impregnated Handsheet Examples 1 through 3 embodying the present invention with the uniform density/pattern impregnated Handsheet

30 Example 6.

Referring now to Table I, the Handsheet Examples 1 through 3 embodying the present invention clearly have superior (lower) bending modulus (i.e. greater flexibility) as compared to the out-of-registration 35 impregnated/pattern densified Handsheet Examples 4 and 5, and as compared to the pattern impregnated/uniform density Handsheet Example 6.

TABLE I

5 Number	Hand- Sheet	Binder on Prod- uct	Area Covered Percent	Total Tensile Strength g/cm	Dry Tensile Strength g/cm	Total Wet Tensile Percent of Dry Total Tensile	Wet Modulus Kg/cm <sup>2</sup>	Bending Total Tensile
	Fibrés	cent of Weight of...	Fibrés	Fibrés	Fibrés	Fibrés	Fibrés	Fibrés
	1	7.82	39.1	388	163	42.0	31.9	
10	2	8.32	38.2	356	140	39.2	21.3	
	3	10.56	51.6	543	235	43.4	31.9	
	4	9.17	65.4	430	163	38.0	45.9	
	5	8.48	60.3	373	157	42.1	43.6	
	6	9.68	58.4	429	164	38.2	67.4	

HANDSHEET EXAMPLES 7 AND 8

15 Two additional Handsheet Examples embodying the present invention were prepared in the same manner and with the same furnish as Handsheet Examples 1 through 3 except the gravure plates were engraved to provide different levels of binder addition. Pertinent data from these two examples are tabulated in 20 Table II; in particular, comparative dry strength and wet strength data which evidences that embodiments of the present invention have greater strength 25 derived from a given amount of binder than the non-pattern densified Handsheet Example 9 described next.

HANDSHEET EXAMPLE 9

30 This handsheet was of relatively uniform density and was formed, dewatered and dried substantially identically to Handsheet Example 6 using the same furnish as for Handsheet Examples 1 through 8. However, whereas Handsheet Example 6 was impregnated by a full-field gravure plate while backed by a

36 x 32 5-shed fabric in the manner shown in Figure 14, Handsheet Example 9 was impregnated in the manner shown in Figure 15; that is, not backed by a fabric. In this instance, the gravure plate 115 was prepared 5 with a pattern identical in size and geometry to the top-surface-plane knuckles of a 36 x 32 5-shed fabric, Figure 6. The gravure pattern comprised 22,500 reservoirs per square inch of reservoirs (3500 reservoirs per square centimetre of reservoirs) 10 and was derived from a 150 x 150 lines per inch (59 x 59 lines per centimetre) screen which was superimposed on a knuckle-pattern print made from the 36 x 32 5-shed fabric 59, Figure 6, to make a negative which was then used in producing an acid etched gravure plate. 15 Therefore, the uniform density Handsheet Example 9 was pattern impregnated in the same pattern as Handsheet Examples 7 and 8 embodying the present invention. However, whereas Handsheet Examples 7 and 8 were pattern densified prior to their being impregnated in their dense zones, Handsheet Example 9 was 20 of uniform density, i.e. having no dense zones.

TABLE II

	Hand- sheet Example	Basis Weight lb/3000 sq ft	Binder Percent of Weight of Fibres	Total Tensile Strength gm/cm	Dry Tensile Strength gm/cm	Total Tensile Strength gm/cm	Wet Percent of Dry Total Tensile	Total Wet Tensile
25	7	16.2	4.64	277	102	36.7		
30	8	16.0	5.40	328	125	38.0		
	9	15.4	5.02	213	69	32.4		

Another benefit which may be derived from the present invention is precipitated by the application of pressure to the binder impregnated dense zones as, referring 35 to Figure 5, the pattern densified embryonic web 20e

(backed by fabric 59) passes through the pressure biased nip intermediate pressure roll 67 and Yankee dryer 75 prior to the final drying and creping of the web. The following example, Example 10, 5 illustrates this.

EXAMPLE 10

Basically, a papermaking machine of the general configuration as papermaking machine 30, Figure 5, was run to produce two families of samples during 10 which run: the percent of latex solids in the binder emulsion in reservoir 85 was incremented from 10 to 25 and then to 40 percent; the after predryer (APD) fibre consistency was varied from about 68 percent to about 91 percent; and samples were taken 15 from adjacent the doctor blade 78 which samples had about zero crepe, and from intermediate roll 66 and pressure roll 67. In the data tabulated in Table IIIa and IIIb, the former samples are 20 designated Pressed Samples, and the latter samples are designated Unpressed Samples; and pairs of samples are designated by pair numbers which pairs each comprise a Pressed Sample and an Unpressed Sample.

TABLE IIIa

EXAMPLE 10

POST IMPREGNATION PRESSING OF DENSE ZONES  
PRESSED SAMPLES VS. UNPRESSED SAMPLES

5	Sample Pair No	Percent Solids in Latex Binder	APD Consistency Percent	Total Wet Tensile Strength		Ratio Pressed to Unpressed (Ratio of Column 4 to Column 5)
				APD Fibre	% of Total Dry Tensile Strength	
				Pressed	Unpressed	
10	1	10	76.0	28.0	28.3	0.99
	2	10	88.9	27.6	26.1	1.06
	3	25	67.6	39.7	32.4	1.23
	4	25	88.7	40.2	27.9	1.44
	5	40	67.6	39.0	31.4	1.24
15	6	40	90.9	31.4	21.5	1.46

TABLE IIIb

EXAMPLE 10

POST IMPREGNATION PRESSING OF DENSE ZONES  
PRESSED SAMPLES VS. UNPRESSED SAMPLES

20	Pair No	Wet Tensile Strength, g/cm					
		Pressed			Unpressed		
		MD	CD	Total	MD	CD	Total
	1	18.1	15.4	33.5	32.7	19.7	52.4
	2	29.1	17.3	46.4	26.0	16.1	42.1
25	3	45.3	31.5	76.8	39.0	24.8	63.8
	4	43.7	32.7	76.4	29.9	17.3	47.2
	5	37.4	28.3	65.7	33.5	23.6	57.1
	6	16.9	21.2	38.1	22.0	16.1	38.1

30 The samples of Example 10 were made on a paper-making machine of the general geometry of machine 30,

Figure 5, using the 60 percent Tongacel/40 percent Grand Prairie Prime (low bond/kraft softwood fibres, respectively), long fibre furnish as used to make Handsheet Examples 1 through 9 described above. This furnish was chosen to produce, if not impregnated in accordance with the present invention, a weak web with less than 59 grams per cm total tensile strength (the sum of the machine direction tensile strength plus the cross machine direction strength). A 0.12 percent fibre consistency pulp slurry of this furnish was distributed on a Fourdrinier wire 33 of a 4-shed satin weave having a 78 x 60, MD x CD filament mesh count per inch (31 by 24 filaments per centimetre). Dewatering was progressively effected while the web was being forwarded on the 78 x 60 Fourdrinier wire, and then on intermediate carrier wire 51 of the same mesh, weave, and material as the Fourdrinier wire to increase the fibre consistency of the web to about 22 percent prior to being transferred to the imprinting carrier fabric 59 which was a 5-shed satin weave of the type shown in Figure 6 and having 31 x 25, MD x CD filaments per inch (12 x 10 filaments per centimetre). Further dewatering was precipitated by vacuum transfer box 61 and the triple vacuum box 62 to provide a fibre consistency of about 32 percent. The result of vacuum transferring from the 78 x 60 intermediate carrier fabric 51 to the 31 x 25 imprinting carrier fabric 59 and the vacuum dewatering thereon caused the web to become pattern densified thereby completing the formation of the pattern densified web: discrete spaced dense zones juxtaposed top-surface-plane knuckles of imprinting carrier fabric 59, and relatively low density spans or portions between those knuckles. These conditions also caused the unsupported portions of the web to be displaced by the vacuum induced differential fluid (air) pressure into the interfilamentary voids

of fabric 59. The air was then predried by blow through predryer 64 to an APD fibre consistency in the range stated above: 68 percent to 91 percent. The web, still disposed on fabric 59 then was forwarded thereon through a full-field 5 pattern, pressure biased gravure impregnating means of the type described hereinbefore which caused the dense zones of the web to be pressed against the gravure cylinder 81 and thereby become impregnated; however, the low density span portions were not so impregnated 10 by virtue of having been sufficiently displaced into the interfilamentary spaces of fabric 59 to substantially obviate their being impregnated by the impregnating means. Additionally, binder impregnation of the low density span portions was substantially 15 obviated by not pressing them against the rotogravure cylinder 81. Rotogravure cylinder 81 was engraved with a full-field pattern of reservoirs (cells) numbering about 3500 per square centimetre and having a total volume of 1.4 microlitres per square centimetre.

20 The binder material used to impregnate the samples of Example 10 was the same latex emulsion as for the hereinbefore described handsheets except: the percent solids was incremented from 10 to 25 and then to 40 percent; and very low levels of commercial defoamers 25 (Foammaster 160L and Colloid 694) were added to suppress foaming of the latex emulsion 25 in reservoir 85 as cylinder 81 rotated therethrough and the excess latex was doctored therefrom. Foammaster 160L was obtained from Diamond Shamrock Corporation, Cleveland, Ohio, and Colloid 694 was obtained from Colloids Inc, Newark, New Jersey.

30 Further with respect to Example 10, backing roll 82, Figure 5, was an 80 Shore A Durometer rubber covered roll; and pressure roll 67 was an 85 Shore A Durometer rubber covered roll. Roll 82 was biased 35 towards cylinder 81 with a force of about 20 pounds

per lineal inch (3.5 kilograms per lineal centimetre); and pressure roll 67 was biased towards Yankee cylinder 75 at 440 pounds per lineal inch (78 kilograms per lineal centimetre). The creping adhesive which was applied to Yankee dryer 75 via spray applicators 77 to enable creping was Gelvatol 20-90; a polyvinyl alcohol/acetate manufactured by Monsanto Co, St Louis, Missouri. After being creped from the Yankee dryer 75 by doctor blade 78, the paper web from which the pressed samples were taken was reeled at the same speed as the Yankee; thus the samples exhibited virtually zero residual crepe so that residual crepe would not be a substantial difference between the pressed samples and the unpressed samples which were obtained as follows. The unpressed samples of Example 10 were obtained by pressing a sheet width, adhesive coated, rotatably mounted spool against the web on fabric 59 running from roll 66 towards pressure roll 67 to accumulate sufficient web on the spool to run samples thereof which were not adulterated by the adhesive on the spool. The samples were tested to obtain the Tables IIIa and IIIb data after being cured for 5 minutes at 300°F (150°C).

Generally, the data in Tables IIIa and IIIb indicate that post-impregnation pressing as described hereinbefore precipitates improved wet tensile strength; and greater wet tensile strength for a 25 percent level of solids in a latex binder emulsion than for either a 10 percent or 40 percent level of solids. Furthermore, post-impregnation pressing also generally improves the ratio of total wet strength to total dry strength of the paper which is generally regarded as a performance parameter for paper towels and the like.

Three more papermaking experiments which are designated and described below as Examples 11, 12 and 13 were conducted to produce papers embodying

the present invention: that is, pattern densified papers having discrete, spaced, binder impregnated zones of high fibre density and otherwise being substantially low bond, high bulk, unimpregnated 5 structures. Data from these examples are tabulated in Table IV.

TABLE IV

	EXAMPLE 11 2-Ply Paper Towel	EXAMPLE 12 2-Ply Paper Towel	EXAMPLE 13 3-Layer Toilet Tissue
5 Basis Weight: pounds per 3000 sq ft (grams per square metre)	34.2 (55.8)	39.2 (63.9)	16.8 (27.4)
Caliper: mils (mm)	33.1 (0.83)	30.0 (0.76)	10.7 (0.27)
10 Dry MD Tensile Strength: grams/inch (grams/cm)	465 (183)	924 (364)	196 (77)
Dry CD Tensile Strength: grams/inch (grams/cm)	346 (136)	559 (220)	144 (57)
15 Wet CD Tensile Strength: grams/inch (grams/cm)	157 (62)	176 (69)	Not measured
Wet/Dry CD Tensile strength	47%	31%	
Wet Tear Strength: grams	56.0	53.0	Not measured
Stretch MD	19%	35%	23%
20 Stretch CD	11%	9%	7%
Softness: Subjective Panel Score Units, Example Versus a Contemporary Paper Product of Comparable Basis Weight	+1.7	+1.0	+1.7
25 Spill Wipe-Up: Subjective Panel Score Units, Example Versus a Contemporary Paper Product of Comparable Basis Weight	-0.4	+0.9	Not measured
Binder Content, Estimated as percent of fibre weight	6%	2%	2.4%
30 Binder: Type	Latex	Polymeric	Latex
35 Concentration	Emulsion 40% Solids	Solution 10% Solution	Emulsion 5% solids

Briefly, Examples 11 and 12 were made using low bond Tongacel, described hereinbefore, in the furnishes to provide low bond webs, and the process conditions were so controlled that the webs were pattern densified 5 when fully formed, and then impregnated with binder material in their dense zones to enhance both their wet and dry strengths: a latex emulsion binder for Example 11 and a polymeric solution type binder for Example 12.

10 More specifically, Example 11 was made from the same 60% Tongacel/40% Northern Softwood Kraft and in the same manner as Example 10 except for a relatively constant APD fibre consistency of 78 percent; and except for the latex binder having 40 percent solids 15 and containing no lithium tracer or dye. After the paper web was creped and doctored from the Yankee dryer, Example 11 was calendered by a rubber/steel calender roll pair at 58 pounds per square inch (400 kPa) and reeled at a speed of 75 percent of the Yankee 20 to provide a relatively high degree of residual crepe. The reels of paper were then combined into 2-ply paper towels with the non-Yankee-contacting sides of both plies in face-to-face relation, and embossed and adhesively secured together as taught by US Patent No 25 3,414,459 which issued December 3, 1968 to E R Wells, and shown in sectional-view Figure 6 thereof. The combined product was cured at 350°F for 3 seconds, reeled, and then tested. The data are tabulated on Table IV. These paper towels exhibited high strength 30 and an extraordinary ratio of wet/dry CD tensile strength as compared to a variety of contemporary paper towels yet scored substantially higher in subjectively perceived softness. Also, the data evidences that the converting process removed a substantial 35 portion of the residual crepe in the paper.

Example 12 was also made on a papermaking machine

of the same general geometry as machine 30, Figure 5, except, a three chamber divided headbox (not shown) was used to deliver two types of fibre slurries onto the Fourdrinier wire 33 in superposed relation.

5 The first-down slurry juxtaposed the Fourdrinier wire was identical to the low bonding pulp slurry of Tongacel/Northern Softwood Kraft which was used to make Examples 10 and 11, and was issued from the bottom chamber of the headbox at a fibre consistency of

10 0.20 percent. Northern Softwood Kraft slurries were simultaneously issued from both the centre and top headbox chambers at a fibre consistency of 0.12 percent. The Fourdrinier wire 33, and intermediate carrier fabric 51 were the same 78 x 60 mesh and weave, respectively, as used for Examples 10 and 11. However, the imprinting carrier fabric 59 was the same 36 x 32, 5-shed mesh and weave as used for Handsheet Example 1. Fibre consistency was 13 percent prior to transfer to fabric 59; 29 percent before predryer (BPD); and

15 96 percent APD.

20

The binder used for Example 12 was a 10 percent solution of Parez 631 NC, a papermaking wet strength resin sold by American Cyanamid Company, Wayne, New Jersey. This is believed to be a reaction product of glyoxal with a copolymer of dialkyl dimethyl ammonium chloride and acrylamide.

25 The rotogravure cylinder used for Example 12 was the same as for Examples 10 and 11; and the web was finished, creped, calendered, reeled, converted to 2-ply paper towels, and tested to the same degree and in the same manner as Example 11 except both plies were oriented to place their low bond layers on the outside of the structure. The resulting data are tabulated in Table IV.

30 Example 13 was formed as a 3-layer structure using

the 3-compartment headbox described above and in the same general manner in the same papermaking machine as Example 12. The three layers consisted of Champion Eucalyptus on the top and bottom and Grand Prairie Prime Northern Softwood Kraft in the middle. The Champion Eucalyptus was obtained from Champion International Corporation, Stamford, Connecticut. All pulps were at 0.13 percent consistency when distributed at three equal basis weights to produce a web on the machine of 17.7 pounds per 3000 square feet (28.9 grams per square metre) basis weight. The kraft layer was made from low bonding pulp furnish which had Quaker 2003 (a stearyl imidazoline made by Quaker Chemical Company, Conshohocken, Pennsylvania) added at a level of about 0.25 weight percent of the kraft. The web was initially formed on the same 78 x 60 Fourdrinier wire used for Examples 10, 11 and 12, and subsequently transferred and dewatered as generally described with respect to those Examples. The imprinting carrier fabric was a 3-shed semi-twill having a mesh count of 31 x 25, MD x CD filaments/inch (12 x 10, MD x CD filaments/cm) and was treated to provide imprinting knuckles as described in US Patent No 3,905,863 which issued September 16, 1975 to P G Ayers. The net result of vacuum transferring from a 78 x 60 intermediate fabric to a 31 x 25 imprinting carrier fabric and subsequent dewatering was to produce a web on the 31 x 25 mesh imprinting carrier fabric of non-uniform density having low density portions juxtaposed the voids in the fabric, and high density zones juxtaposed the fabric knuckles.

The latex binder used was Airflex 402 which was obtained from Air Products and Chemicals Inc, Allentown, Pennsylvania; a dry strength vinyl-acetate ethylene emulsion. This was adjusted to have a 5% level of

solids, and applied by the same rotogravure cylinder of Example 10. The impregnated web, still disposed on and in register with the 31 x 25 imprinting carrier fabric, was then pressed at 440 p.l.i (78 kilograms per lineal centimetre) against the Yankee dryer, using a rubber covered pressure roll with a Shore A Durometer hardness of 85 loaded against the dryer to imprint the knuckle pattern of the fabric into the web and thereby compact the dense zones thereof.

5 Gelvatol 20-90 polyvinyl alcohol/acetate manufactured by Monsanto was applied to the Yankee dryer upstream from the pressure roll to adhere the web to the Yankee and allow creping at the doctor blade after the web was dried. The web was then run through a rubber roll/

10 steel roll papermaking calendering nip at a light load and wound up on a reel at 82% of the Yankee speed. The reels of paper thus obtained were rewound and

15 slit into standard toilet tissue rolls and tested. The test data are tabulated in Table IV.

Claims

1. A pattern densified fibrous web comprising a relatively high bulk field having a relatively low fibre density, and a patterned array of spaced zones of relatively high fibre density integrated with said relatively high bulk field, characterised in that at least a substantial proportion of said high density zones are at least partially impregnated with binder material and said high bulk field is substantially devoid of said binder material.
- 5 2. A pattern densified fibrous web according to Claim 1 characterised in that the surface portions of said zones which are impregnated with said binder material constitute from 25 to 75 percent of the corporate surface area of said zones.
- 10 3. A pattern densified fibrous web according to either of Claims 1 and 2 wherein one surface of said web is substantially wholly free of said binder material.
- 15 4. A pattern densified fibrous web according to Claim 1 characterised in that all of said high density zones are substantially fully impregnated by said binder material.
- 20 5. A pattern densified fibrous web according to any one of Claims 1-4 characterised in that said high density zones have a corporate surface area which constitutes from 10 to 50 percent preferably from 20 to 40 percent of the total surface area of said web.
- 25 6. A pattern densified fibrous web according to any one of Claims 1-5 characterised in that it comprises a principal web-strength fibre constituent of sufficient average length with respect to the spacing of impregnated high density zones that a substantial fraction of said fibres will have spaced portions thereof disposed in adjacent impregnated high density zones and in overlapping bonded relation with portions of other fibres so that said fibres constitute a strength-skeletal-network of said web.
- 30
- 35

7. A pattern densified fibrous web according to  
Claim 6 wherein the fibres constituting said  
principal fibre constituent are papermaking fibres  
having average lengths of 2.0 mm or more.

5 8. A pattern densified fibrous web according to  
either one of Claims 6 and 7 wherein said web has  
a low degree of interfibre hydrogen bonding.

9. A pattern densified fibrous web according to  
Claim 8 wherein said web incorporates a fibre-  
10 debonding material.

10. A pattern densified fibrous web according to  
Claim 8 wherein the web comprises papermaking fibres  
having a low inherent interfibre hydrogen bonding  
propensity.

15 11. A method of making a pattern densified, partially  
impregnated fibrous web comprising a multiplicity of  
discrete zones of relatively high fibre density in  
which web at least a substantial proportion of said  
zones are at least partially impregnated with a non-  
fibrous impregnating material, said method comprising  
20

forming a fibrous, pattern densified embryonic  
web having a multiplicity of discrete zones of  
high fibre density which zones are disposed in a  
predetermined patterned array, and drying said  
embryonic web, characterised in that it comprises  
25 the steps of supporting said embryonic web on an  
array of spaced supports so that each of a pre-  
determined sub-array of said zones is juxtaposed  
one of a predetermined sub-array of said supports,  
30 and  
at least partially impregnating at least a  
substantial proportion of the supported predeter-  
mined sub-array of said zones with an impregnating  
material by biasing said predetermined sub-array  
35 of said supports towards a contacting type impreg-  
nating means with said sub-array of said zones

disposed between said sub-array of said supports and said impregnating means.

12. A method according to Claim 11 wherein said supports comprise outward facing knuckles of a loop of an imprinting carrier fabric, said fabric having meshes in the range of from 4-MD/4-CD to 24-MD/24-CD filaments per centimetre, preferably from 8-MD/8-CD to 20-MD/20-CD filaments per centimetre.

13. A method according to either one of Claims 11 and 12 wherein said web comprises a principal web-strength fibre constituent of fibres of sufficient average length with respect to the spacing of said supports constituting said predetermined sub-array of said supports that after said web is formed a substantial fraction of said fibres will have spaced portions thereof disposed on adjacent supports of said sub-array of said supports and in overlapping relation with portions of other fibres whereby said fibres constitute a strength-skeletal-network of said web with said overlapping portions of said fibres bonded together.

14. A method according to any one of Claims 11-13 characterised in that said impregnating material comprises a binder material.

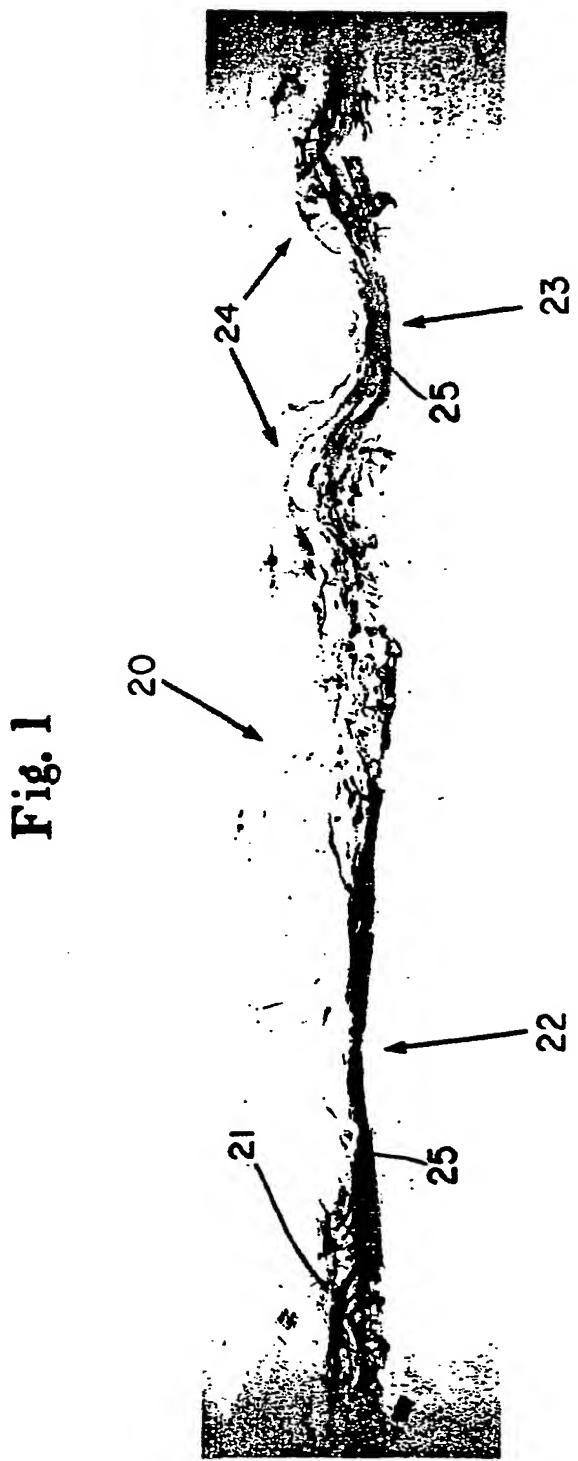
25 15. A method according to Claim 14 wherein said aqueous fibrous slurry comprises a fibrous furnish of sufficiently low inherent interfibre bonding propensity that said embryonic fibrous web would have insufficient integral structural integrity to be self supporting while being impregnated with said binder material.

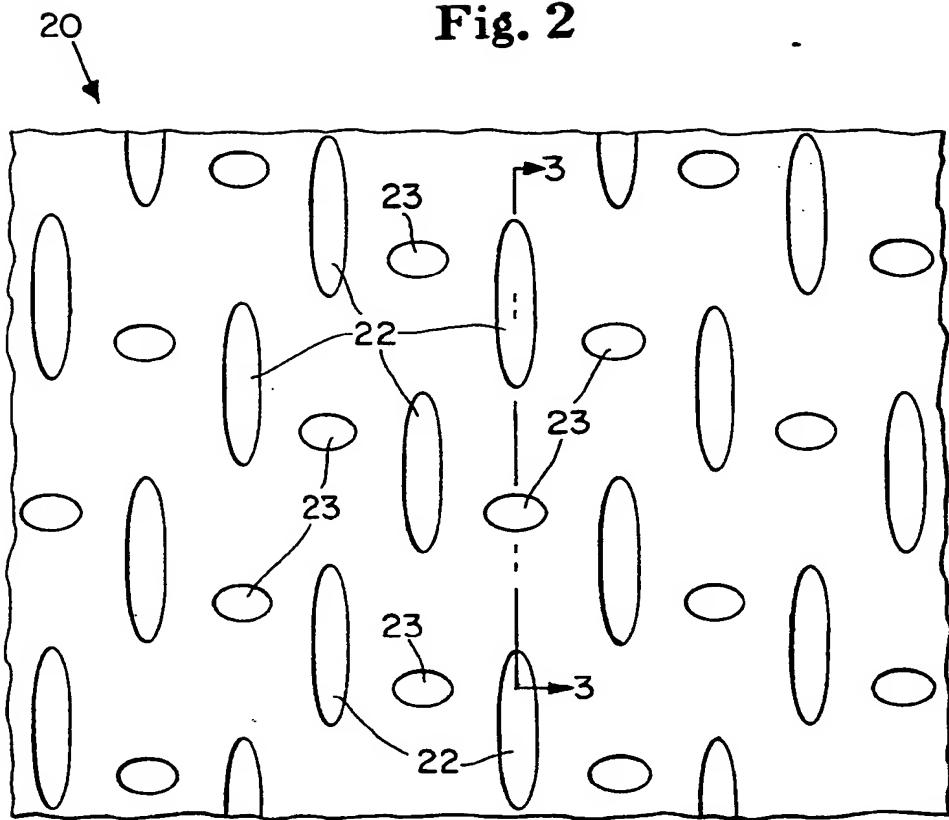
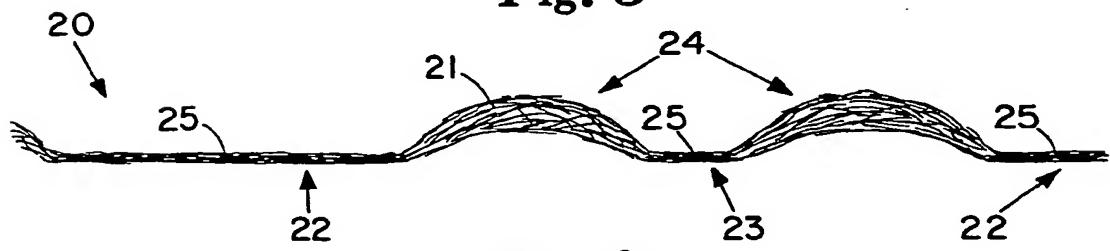
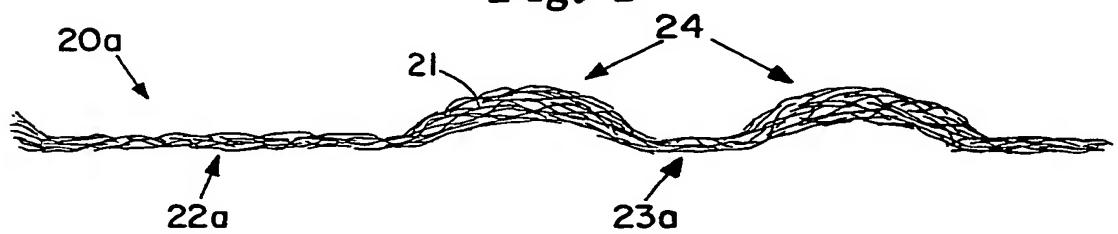
30 16. A method according to any one of Claims 11-15 characterised in that it comprises the step of drying said embryonic web in the absence of substantial mechanical compression to an average fibre consistency of from 30 to 95 percent preferably from 60 to 90 percent prior to said impregnating.

17. A method according to Claim 16 characterised in that said drying is effected in such a manner that the unsupported spans of said embryonic web are dried substantially more than the supported zones of said embryonic web.
18. A method according to Claim 17 wherein said drying is effected by blow through drying means while said web is supported on said supports.
19. A method according to any one of Claims 11-18 characterised in that it comprises the further step of sufficiently deflecting the spans of said embryonic web disposed intermediate said spaced supports into the spaces disposed intermediate said supports to substantially obviate impregnating said spans when said sub-array of said supports is biased towards said impregnating means.
20. A method according to Claim 19 wherein said deflection is effected by applying a differential fluid pressure across said supported web.
21. A method according to any one of Claims 11-20 characterised in that it comprises the further step of subjecting said supported zones to substantial mechanical compression after said impregnating has been effected.
22. A method according to any one of Claims 11-21 characterised in that said predetermined sub-array of said supports coacts with an impregnation pattern of said impregnating means so that said impregnating material is applied to only the portions of said zones disposed intermediate registered areas of said predetermined sub-array of said supports and said impregnating pattern during said impregnating.

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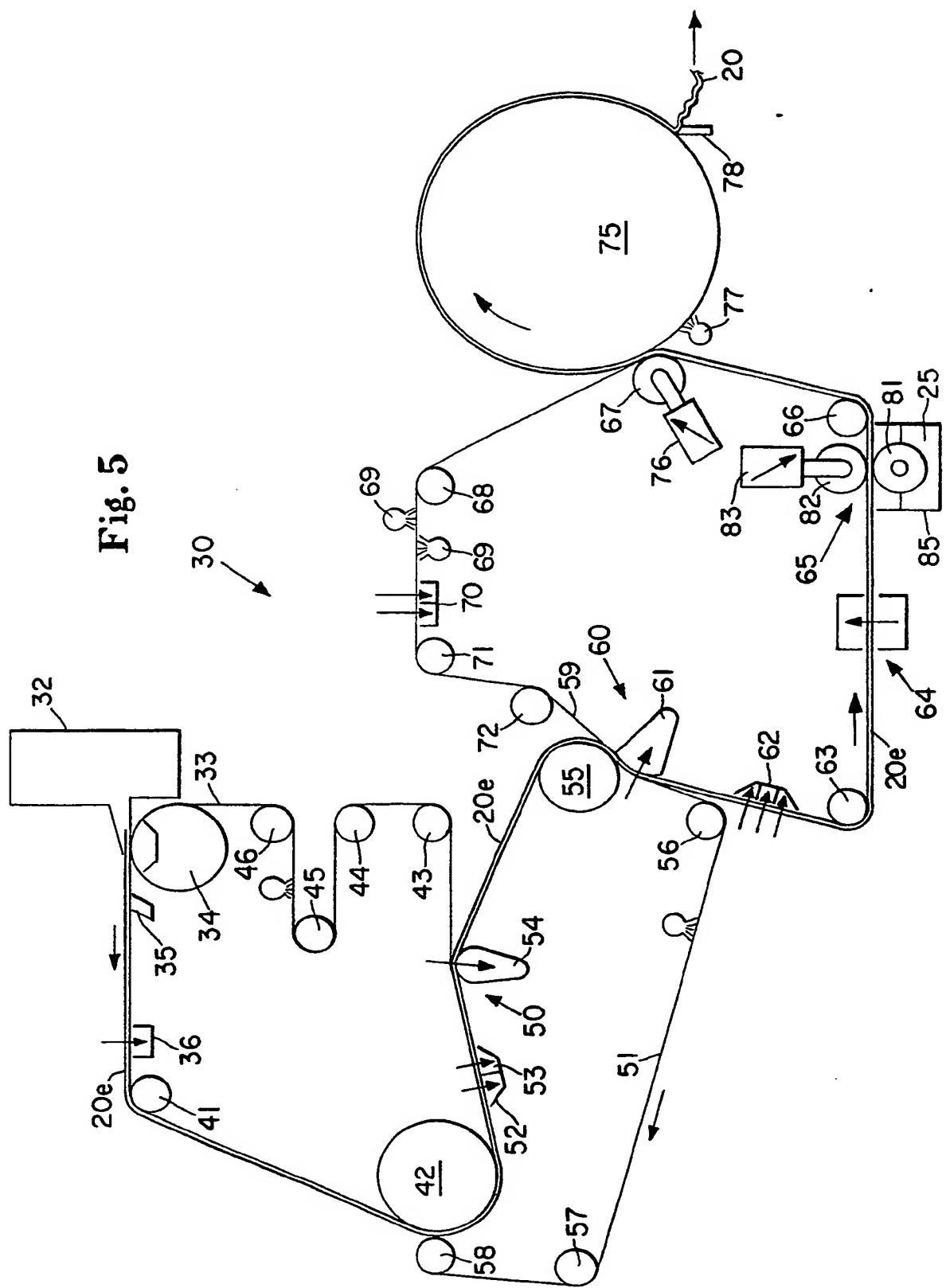
1/11



**Fig. 2****Fig. 3****Fig. 4**

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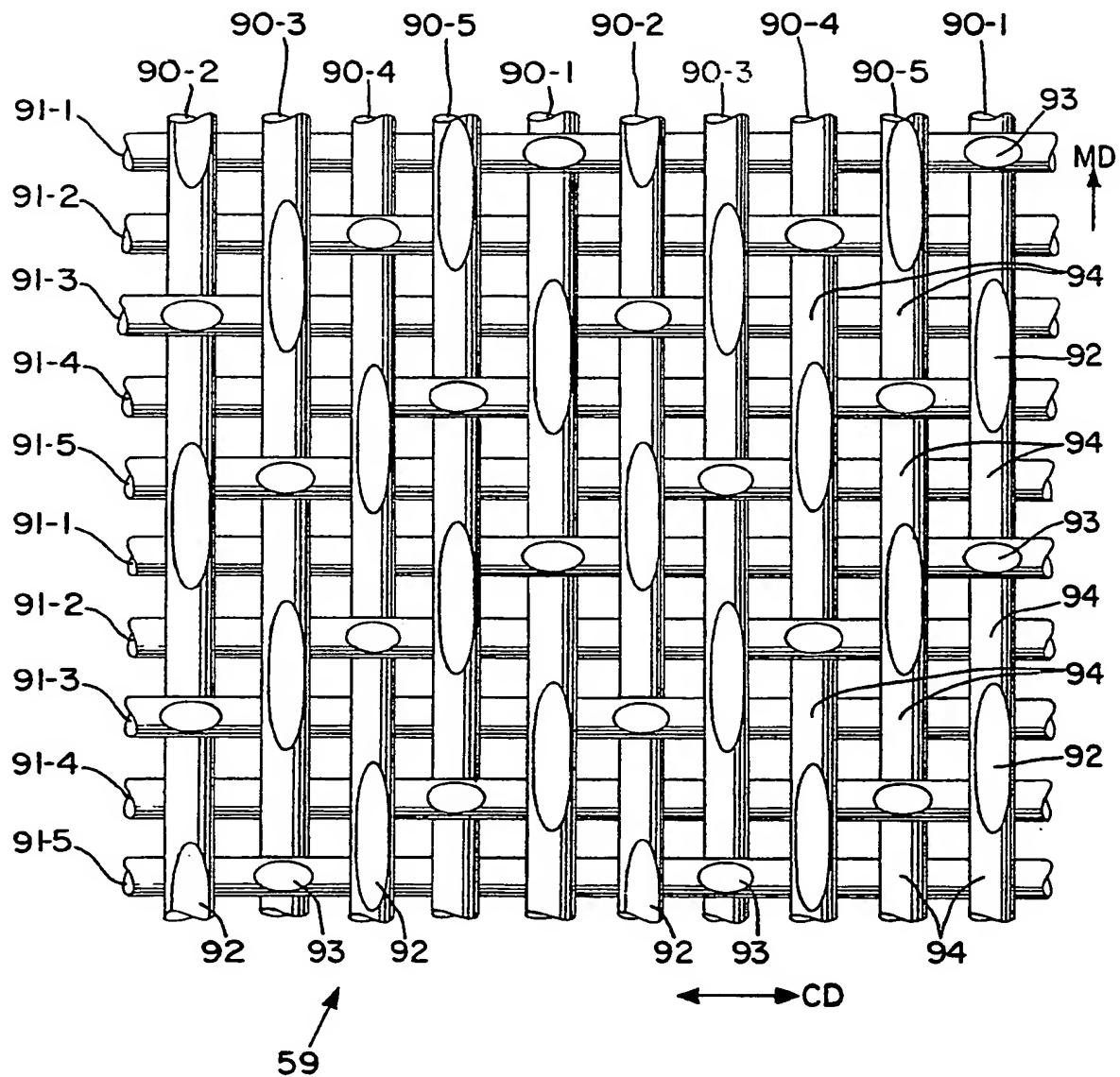
3/11



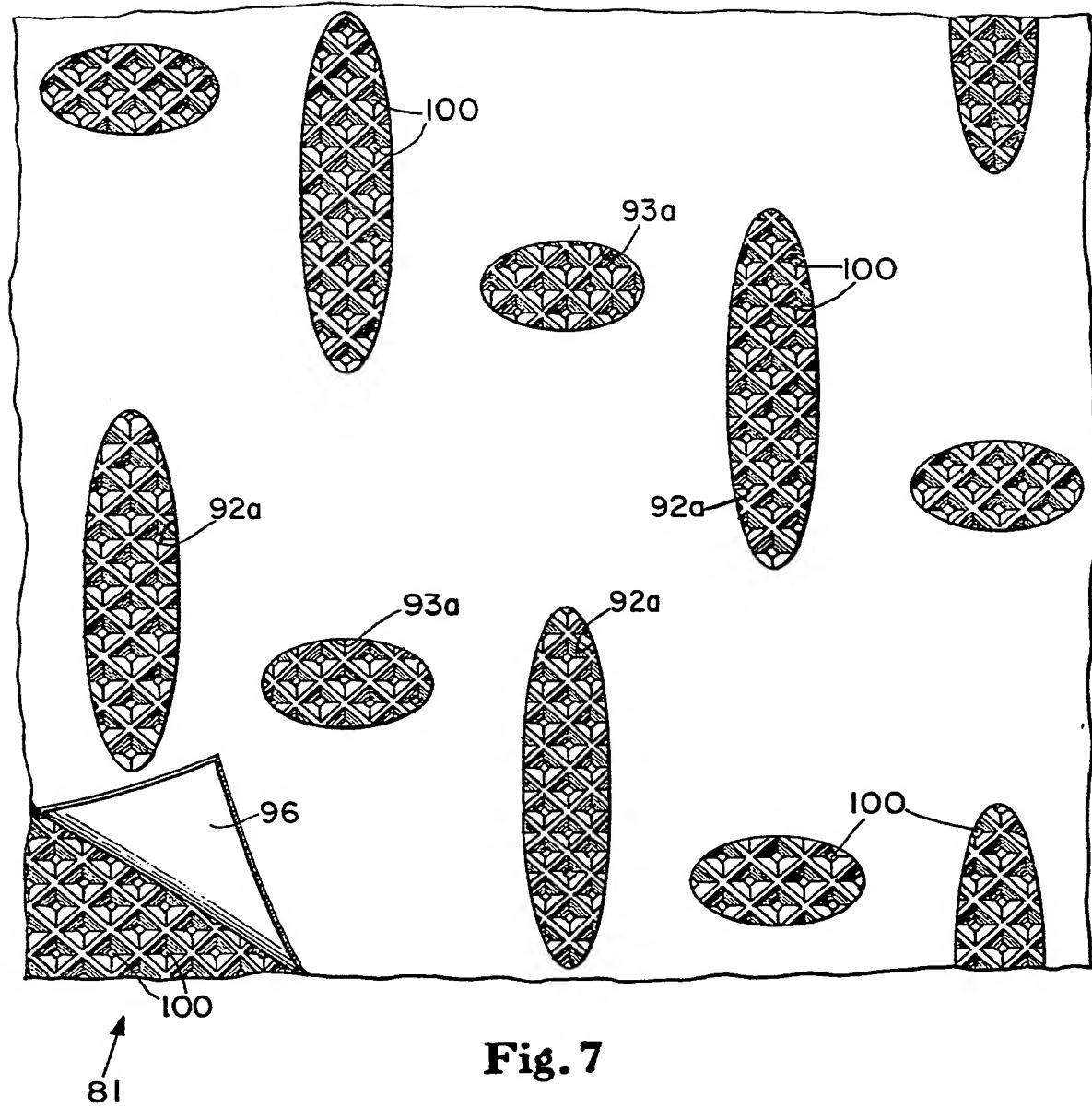
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4/11

**Fig. 6**



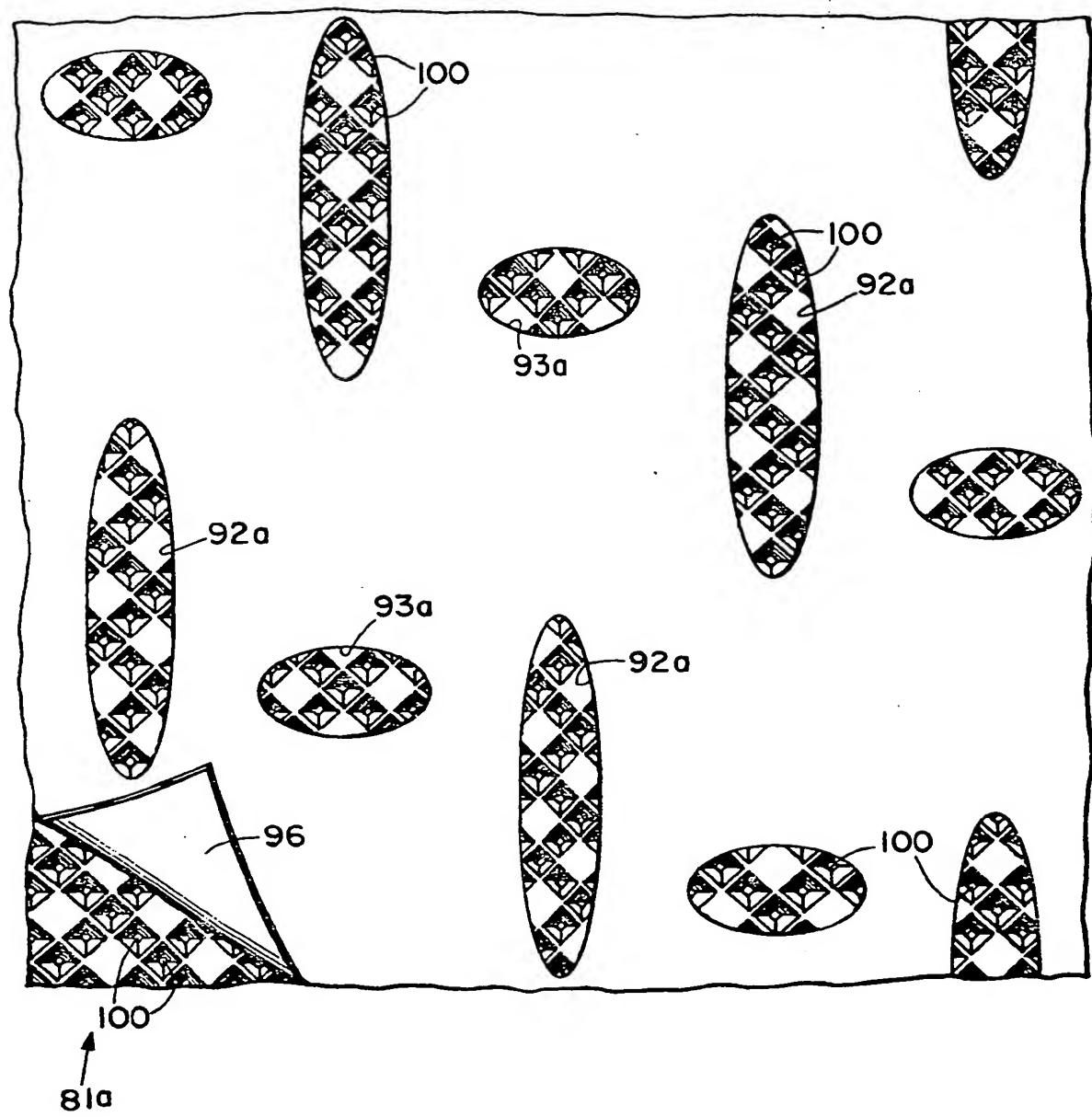
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6/11

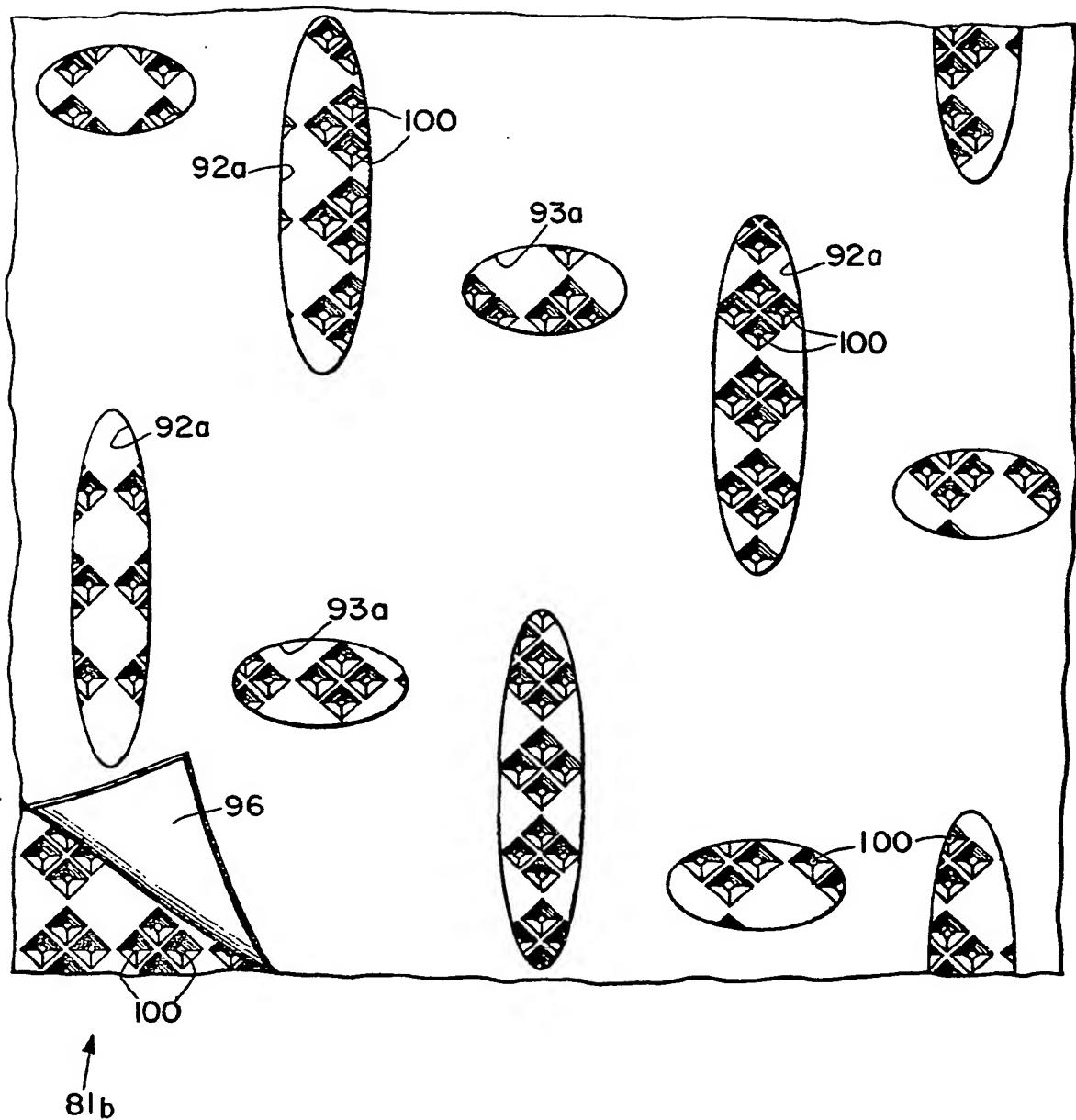
Fig. 8



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7/11

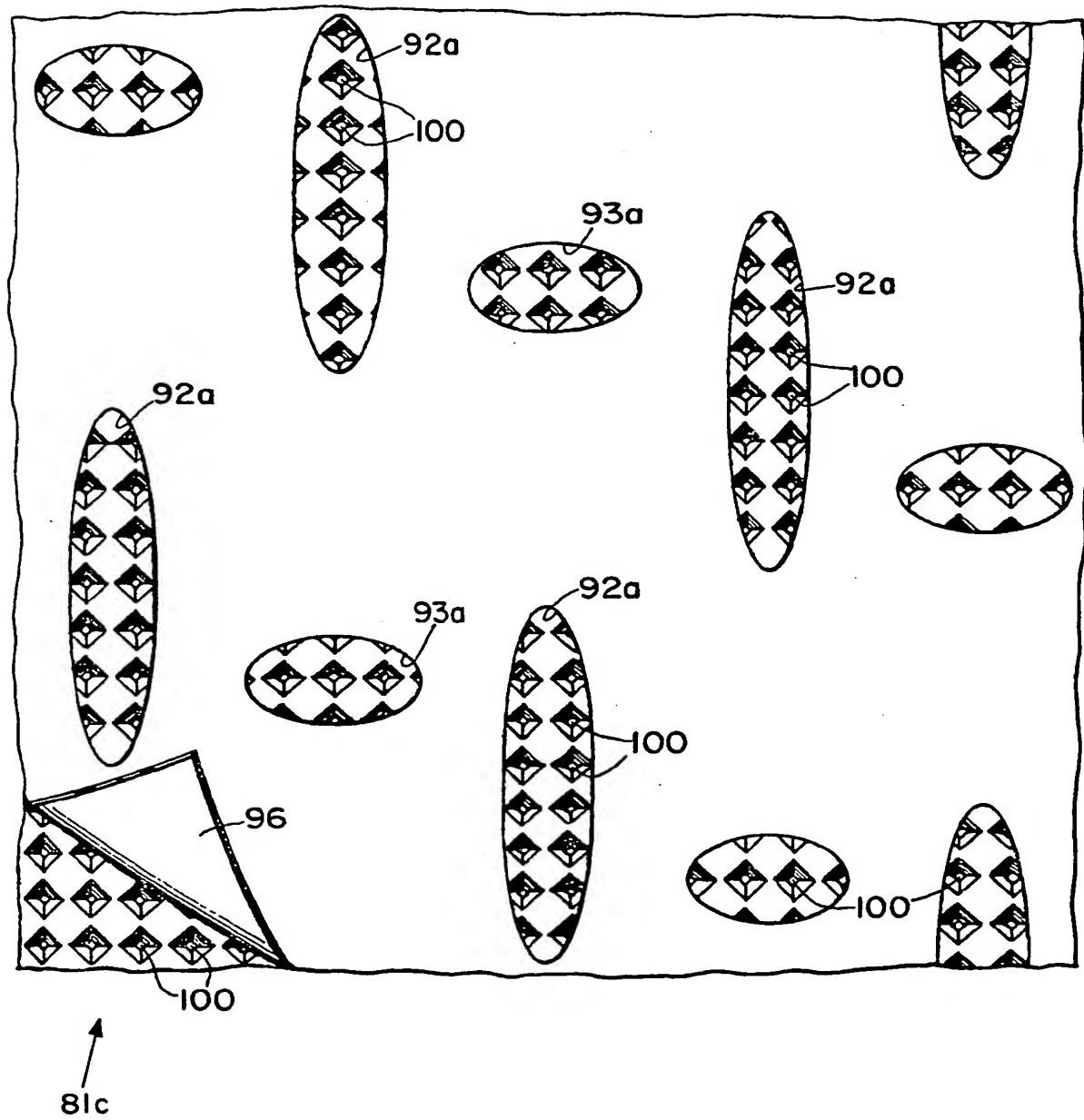
Fig. 9



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8/11

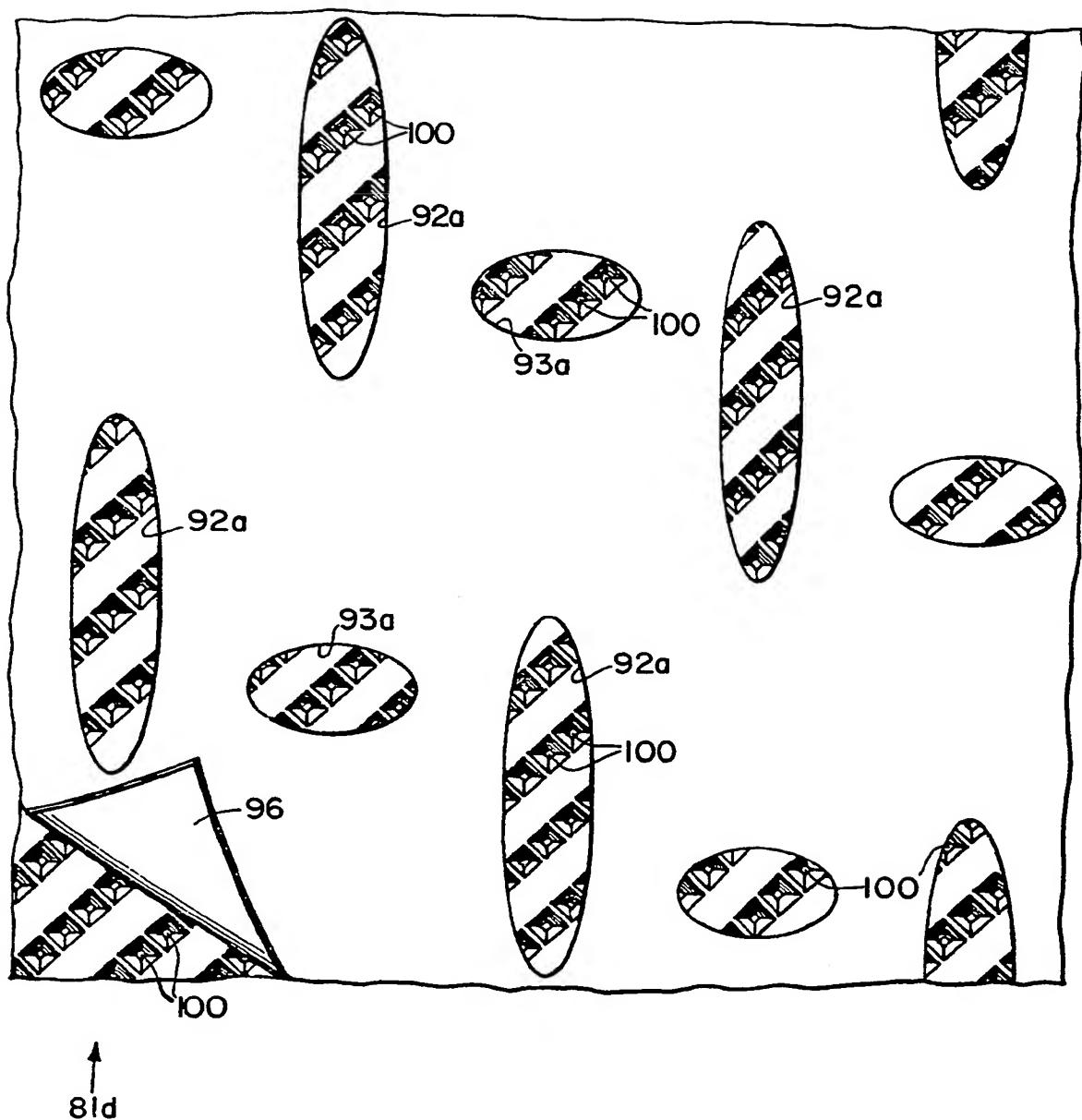
Fig. 10



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9/11

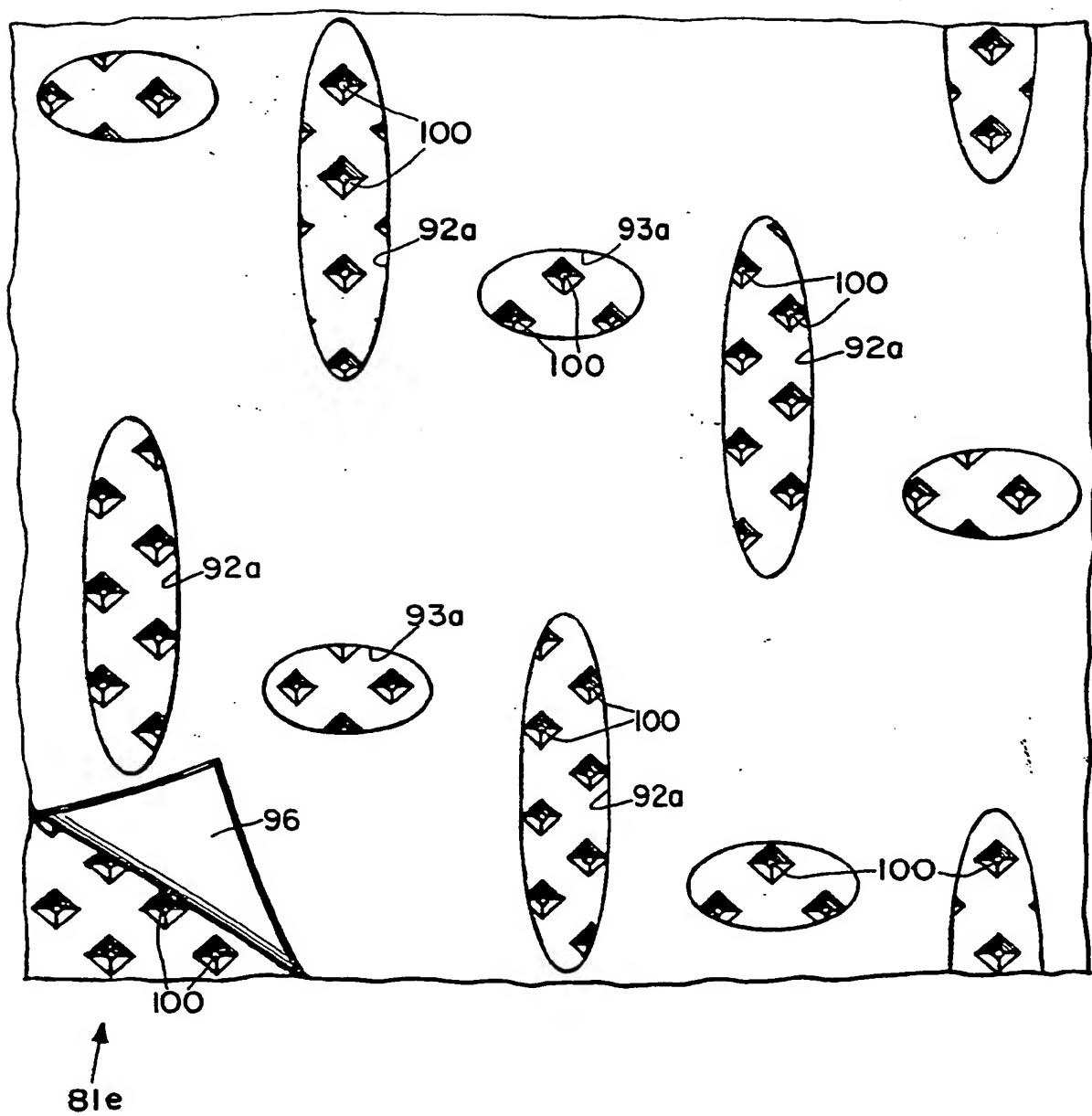
Fig. 11



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10/11

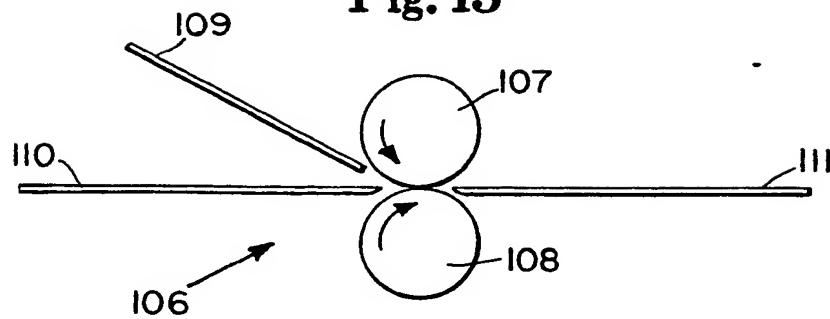
Fig. 12



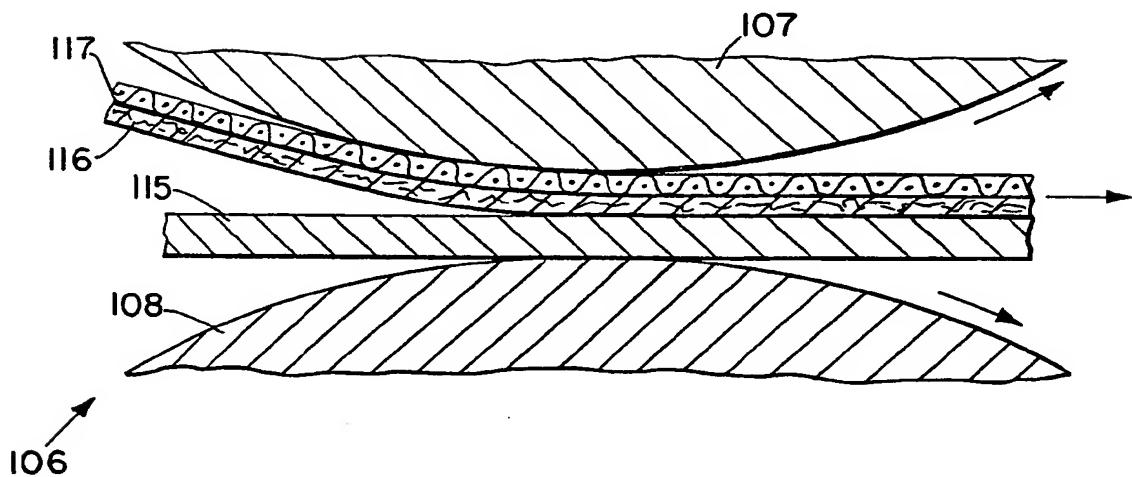
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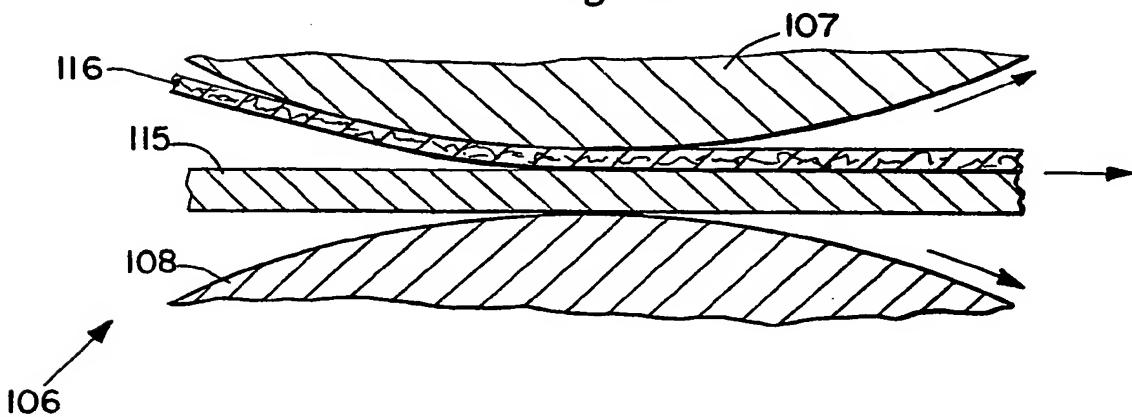
**Fig. 13**



**Fig. 14**



**Fig. 15**





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0 033 988  
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## EUROPEAN PATENT APPLICATION

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⑯ Date of publication of application:  
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⑯ Date of deferred publication of search report: 16.09.81

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⑯ Designated Contracting States:  
AT BE CH DE FR GB IT LU NL SE

⑰ Representative: Gibson, Tony Nicholas et al,  
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⑲ Pattern densified fibrous web having spaced, binder impregnated high density zones, and method of making such a web.

⑳ A soft, pattern-densified fibrous web (20) such as a paper sheet, which web generally comprises a relatively low-bond, high-bulk vaulted field (24) and a patterned array of spaced zones (22, 23) of relatively high fibre density, at least a substantial proportion of which dense zones are at least partially impregnated with binder material (25). The degree of impregnating and bonding in the dense zones may be increased by applying mechanical compression to the impregnated zones subsequent to applying the binder material.

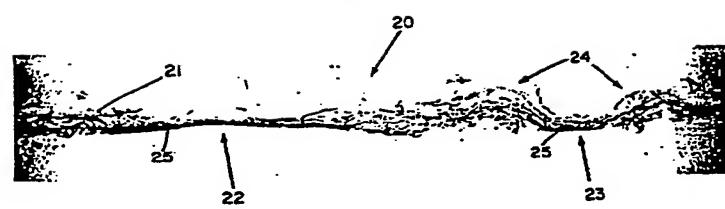
The method of making such a web generally entails forming a low-bond pattern-densified fibrous web, supporting dense zones (22, 23) of the web on a patterned array of spaced supports, displacing the unsupported portions of the web into the spaces intermediate the spaced supports, and applying a binder material (25) to dense supported zones of the web.

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Fig. 1





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Office

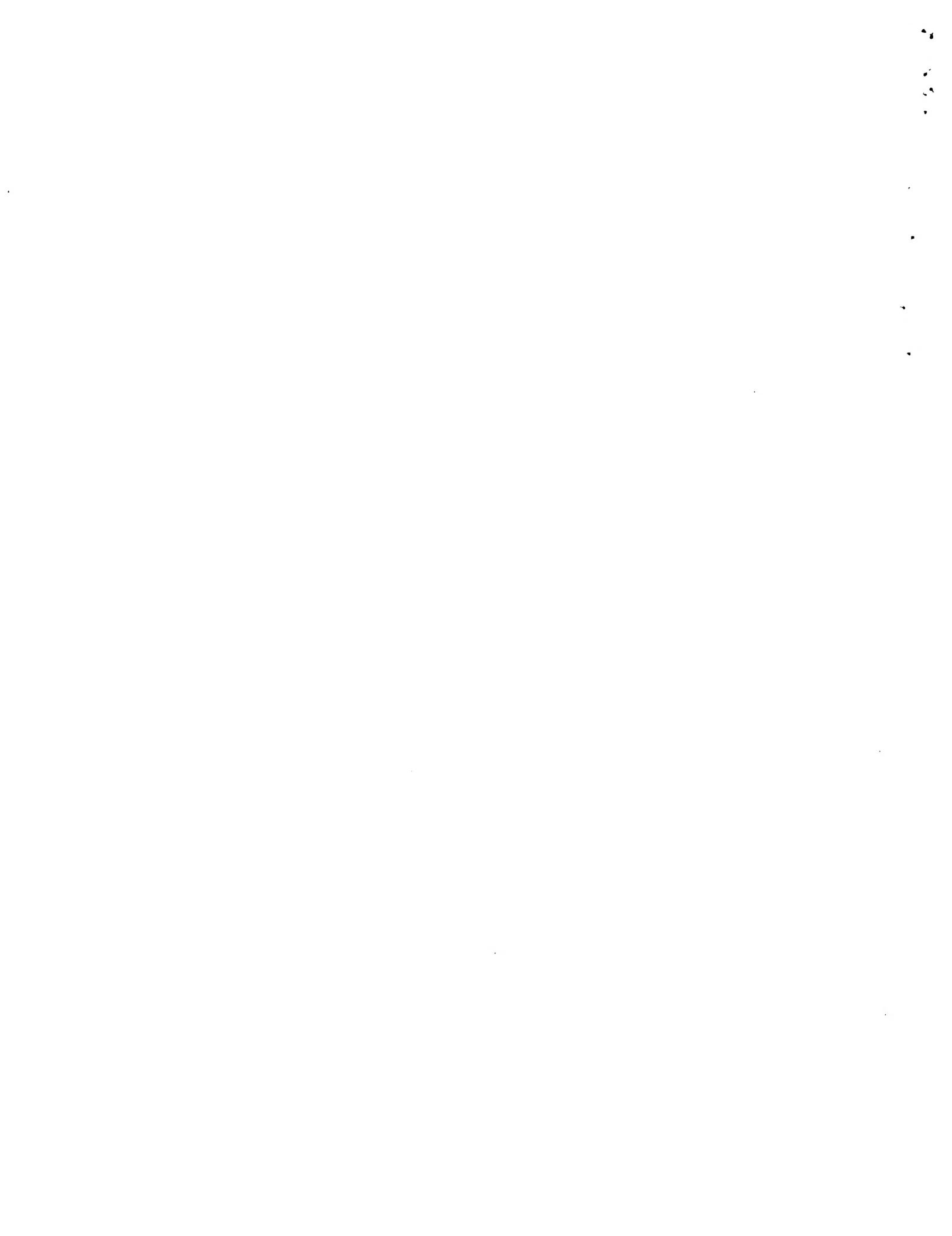
EUROPEAN SEARCH REPORT

0033988

Application number

EP 81 20 0093

DOCUMENTS CONSIDERED TO BE RELEVANT			CLASSIFICATION OF THE APPLICATION (Int. Cl.)
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	TECHNICAL FIELDS SEARCHED (Int. Cl.)
X	<u>US - A - 3 692 622</u> (C.E. DUNNING)	1,4-7, 10	D 21 D 3/00 D 21 H 5/02
	* Claims 1,2; figures 1-3,5-10; column 2, line 65 to column 4, line 68; column 5, lines 29-44; column 6, lines 26-57; examples VII and X *	---	
X	<u>US - A - 3 776 807</u> (C.E. DUNNING et al.)	1,4-8, 10	
	* Claims 1-4; figures 1-4; column 2, line 64 to column 5, line 6; column 6, lines 30-52 *	---	
X	<u>US - A - 2 958 608</u> (K.H. BARNARD)	1,5-8, 10	D 04 H 1/66 D 21 D 3/00 D 21 F 11/00 D 21 H 5/02 D 21 H 5/24 D 21 H 5/26
	* Claims 1,2,4,5; figures 1-4,7; column 2, lines 33-43; column 3, line 15 to column 5, line 46 *	---	
	<u>US - A - 3 755 220</u> (B. FREIMARK et al.)	7,9	
	* Claims 1 and 4 *	---	
	<u>US - A - 4 134 948</u> (J.H. BAKER Jr.)	11,13, 14	
	* Claims 1-4; figures 1-3; column 2, line 18 to column 3, line 3; column 7, lines 21-55 *	---	
D/A	<u>US - A - 3 301 746</u> (L.H. SANFORD et al.)	11-14, 15-18	CATEGORY OF CITED DOCUMENTS
	* The entire document *	-----	X: particularly relevant A: technological background O: non-written disclosure P: intermediate document T: theory or principle underlying the invention E: conflicting application D: document cited in the application L: citation for other reasons
			&: member of the same patent family, corresponding document
The present search report has been drawn up for all claims			
Place of search	The Hague	Date of completion of the search	Examiner
		26.06.1981	NESTBY



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